Third Semester and Master's Thesis Ideas 2017

M.Sc. in Civil and Structural Engineering

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Edited by Johan Clausen

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Johan Clausen

May 2017

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M.Sc. in Civil and Structural Engineering: Third Semester and Master Projects Ideas

The following pages contain a list of project ideas proposed by the scientific staff at the Department of Civil Engineering, Aalborg University, and a number of companies. The project ideas in this catalogue may form the basis for long and short master projects as well as regular 3rd semester projects at the M.Sc. programme in Civil and Structural Engineering. On some of the project proposals it is stated which type of project the proposal is suitable for. For the rest of the proposals this question should be discussed with the potential supervisor.

Each project description provides a brief overview of the purpose as well as the main activities. Further, a weighting between theoretical analysis, experimental work and computer modelling has been proposed. Usually, this weighting can be changed slightly in accordance with the wishes of the students. The contact persons listed will usually act as supervisors. Questions regarding details about each proposed project should be directed at the contact persons. The contact details can be found via a person search on the university home page. Furthermore, other ideas for projects may be discussed with a potential supervisor. In this aspect the proposals in this catalogue can reveal the expertises and research areas of the different supervisors.

Many private engineering companies have a homepage on which they state that they would like to collaborate with students on a master project. Find out more on the individual company home pages.

The preferred group size for master projects is two to three students. In the interest of students as well as supervisors, single-student projects are generally not recommended. In a short third semester project the recommended minimum group size is three students, some supervisors may require more.

At the third master semester the students have the option of doing a company stay. It is important to realise that this is not a traditional internship, but rather a third semester project carried out in cooperation with a private or public company. An example of a successful subject for such a company stay is also given in this catalogue in the last page. The student is not allowed to receive a salary from the company, as the stay is considered a full time study, and as such the student still receives SU.

A final remark about master projects: A signed thesis contract must be handed to your study secretary at latest October 1st for long master projects and March 1st for short master projects. The contract must contain information about the project, in particular regarding the educational goals. These must be defined in accordance with the Master Curriculum (danish: Studieordningen) for the M.Sc. Programme in Civil and Structural Engineering at the School of Engineering and Science, Aalborg University. The curriculum can be found at the Study Board of Civil Engineering homepage at http://www.ses.aau.dk/digitalAssets/83/83075_curriculum-for-the-master-s-program-in-structural-and-civil-engineering-2010.pdf. The thesis contract

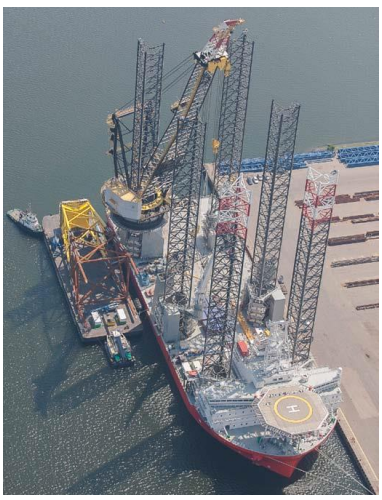
template is the online form available at the homepage of the School of Engineering and Science at http://www.ses.aau.dk/til-studerende-ansatte/blanketter-regler/ansoegningsskemaer-blanketter/thesis-contract/. The delivery date for the project report will be set by the Study Board. It is usually between June 1-8 for Master theses. For third semester projects, the thesis contract is not needed.

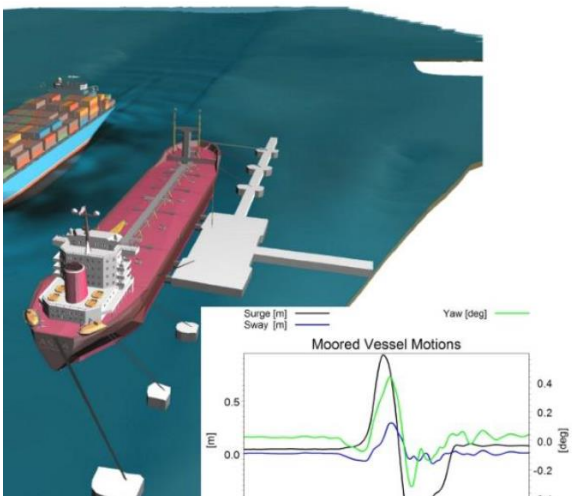
Aalborg, May 3, 2017 Johan Clausen, *semester coordinator*

Mooring behaviour of vessels in ports

Purpose: The purpose is to make use of a mooring analysis tool within the MIKE 21 MA suite and assess the suitability of the existing design guidelines in PIANC on allowable wave disturbance for assessment of downtime in ports.

A newly featured tool being available in the MIKE21 software toolbox from DHI is supposed to be used/ validated in combination with e.g. physical model tests and/or state of art knowledge for the evaluation of moored vessel response in ports. The tool can be coupled with a Boussinesq model to simulate the floating behaviour of moored vessels in a port. The most used guidelines on "allowable" wave disturbance in ports are relatively primitive and the present project should investigate alternative and more sophisticated methods.





Main activities: The project will contribute to the on-going research and development on the subject and thus the following activities can be included:

- Combined numerical modelling of wave disturbance and floating behaviour of moored ships in a port
- Validation of MIKE 21 MA suite for modelling of moored ship movements

Contact persons: Jørgen Harck Nørgaard, Thomas Lykke Andersen

Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☐ **short master:** ☒ **Long master** ☒

Wave loads on concrete caisson during installation

Purpose: The purpose is to estimate the wave loads on a concrete caisson during installation where it is filled with water and before ballast material is installed. Under such situation there will be wave induced pressure on also the inner walls. COWI has estimated that omission of these pressures may lead to a significant contribution to the overall fatigue loads on the caisson walls. This project aims at studying the wave induced loads on the wall of the caisson (numerically and/or through model tests) and is carried out in close cooperation with COWI and actual projects.

Main activities: The aim is to develop a simplified model for the loads on the caisson walls before the caisson is ballasted. In order to develop and calibrate such model CFD modelling and/or experimental model tests should be carried out.

Contact persons: Thomas Lykke Andersen, Morten M. Kramer

Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

ULS loads on SPAR type floating wind turbine

Purpose: Wind turbines are placed in deeper and deeper waters and thus bottom fixed structures might not continue to be the best alternative. Several consultancy companies have already started to look at floating support structures for offshore wind turbines. One of the companies is COWI who this project is carried out together with. The calculation of ULS loads on a SPAR type floating wind turbine are associated with high uncertainty and the purpose of the project is to quantify and reduce this uncertainty by application of advanced methods (numerical and/or experimental).

Main activities: The aim is to compare several methods for estimation of ULS loads on a SPAR type floating wind turbine and quantify uncertainties. Examples of methods that can be compared are: diffraction theory, CFD model, integrated load model, experimental model tests.

Contact persons: Thomas Lykke Andersen, Morten M. Kramer

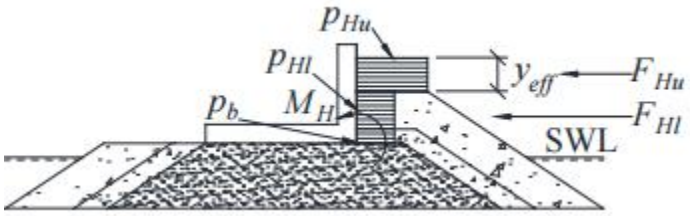
Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐
Suitable project type(**s**): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

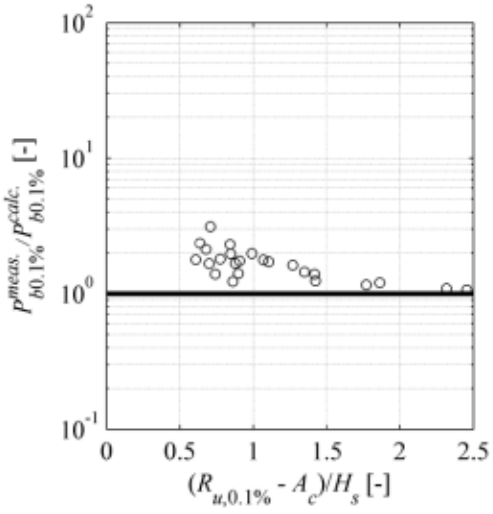
Reanalysis of wave loads on breakwater crown walls

Purpose: The purpose is to extend the formula by Nørgaard et al. (2013) for wave load calculation on breakwater crown walls. The formulae can be extended to include the roughness effect from the armour units. Furthermore, is the prediction of the pressure at the corner (p_b) under-predicted when the wave run-up is equal to or below the crest elevation A_c. Therefore, modifications to the present formula should be performed such that the formula is also valid for low run-up levels.

New tests in the flume at AAU should also be performed if white spots in previous tests are identified.

Contribution: The project can contribute to an on-going PhD study that is working with response of structures exposed to long waves, and the suggested project is a natural extension of this work.





Main activities:

- Extend present formulae to include different armour types and low wave run-up levels

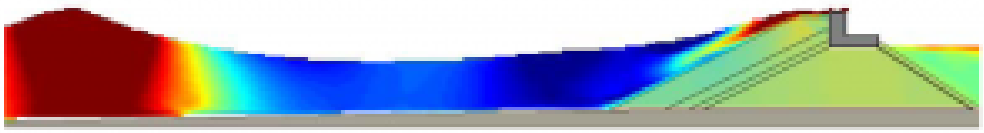
Contact persons: Mads Røge Eldrup, Thomas Lykke Andersen

Theory: ☒☒☒ **Experimental work:** ☒☒☐ **Computer modelling:** ☐☐☐
Suitable project type(s): **3rd sem:** ☐ **short master:** ☒ **Long master:** ☐

Wave height distributions and wave attack on coastal protection structures in highly non-linear deep and depth limited irregular wave conditions

Purpose: Most state of art design formulae for estimation of influence from wave attack on coastal protection structures (stability of superstructures, stability of armour layer, wave overtopping, etc.) are based on relatively linear wave conditions. However, many coastal protections structures are located in relatively shallow water wave conditions with long waves, i.e. non-linear wave conditions.

Recent research has indicated that the existing design tools might provide unsafe predictions in non-linear wave conditions and moreover existing wave height distributions are seen to underestimate the highest wave heights during a storm. The purpose of this study is to evaluate the influence of wave non-linearity and to derive modifications to existing design formulae and wave height distributions based on physical model tests or numerical models.



Main activities: The project will contribute to the on-going research on the subject and thus the following activities can be included:

- Experimental and/or numerical modelling of wave height distribution in deep and depth limited non-linear wave conditions
- Experimental and/or numerical modelling of wave run-up, wave overtopping, and armour stability on rubble mound breakwaters in non-linear wave conditions
- Experimental and/or numerical modelling of dynamic wave loads on rubble mound breakwater crown walls in non-linear wave conditions

Contact persons: Jørgen Quvang Harck Nørgaard, Thomas Lykke Andersen

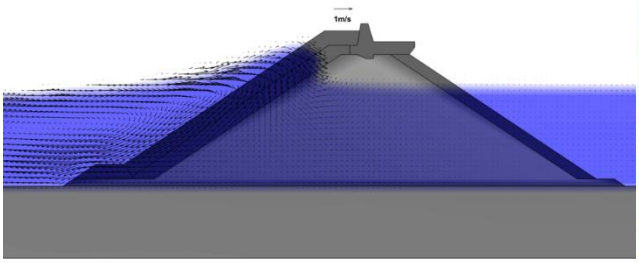
Theory: ☒☒☐ Experimental work: ☒☒☐ Computer modelling: ☒☒☐
Suitable project type(s): 3rd sem ☐ short master: ☒ Long master ☒

Influence of breakwaters permeability on wave overtopping

Purpose: The purpose is to investigate the overtopping discharge for breakwaters with different core permeabilities and crest widths. Today the most used overtopping formulae are only separating into *Permeable* and *Impermeable core*. Therefore, new model tests and/or numerical simulations (CFD-VOF) should be performed to clarify the effect of permeability on overtopping.
The tests made in the numerical model should be verified/calibrated against physical model tests performed in the new wave flume at AAU.

Contribution: An on-going PhD study has found that overtopping caused by long waves is underestimated by state-of-the-art formulae, and the suggested project is a natural extension of this work.

Example of numerical model



Example of physical model

Main activities:

- Clarify relevant permeabilities and cross-sections to study
- Experimental and/or numerical modelling of overtopping discharge

Contact persons: Mads Røge Eldrup, Thomas Lykke Andersen

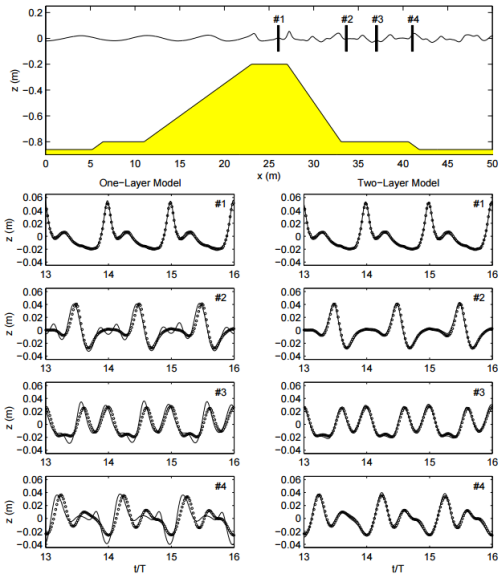
Theory: ☒☐☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem:** ☐ **short master:** ☐ **Long master:** ☒

Improvement of numerical boussinesq wave model

Purpose: The COULWAVE numerical boussinesq wave model (open source) is an extension of the traditional depth integrated bousinesq model to two vertical layers. The additional layer makes it possible to use the model in deeper water than the conventional model. The model might be used for example to transform offshore waves into shallow water with inclusion of the nearshore effects (shoaling, wave breaking and nonlinear wave interactions).

In COULWAVE so far only 1st order irregular wave generation has been implemented and only up to two vertically layers. The purpose of this project is to extend the COULWAVE model with 2nd order wave generation and to increase the number of vertical layers. By increasing the number of layers the computational effort is also increased and thus implementation of GPU support might be relevant to decrease the computational time. The extended model should be validated by physically experiments in the new wave flume at AAU.

Contribution: The improved model would contribute to the existing wave generation software AwaSys developed at AAU by providing a surface elevation for the shallow water wave generation.



Main activities:

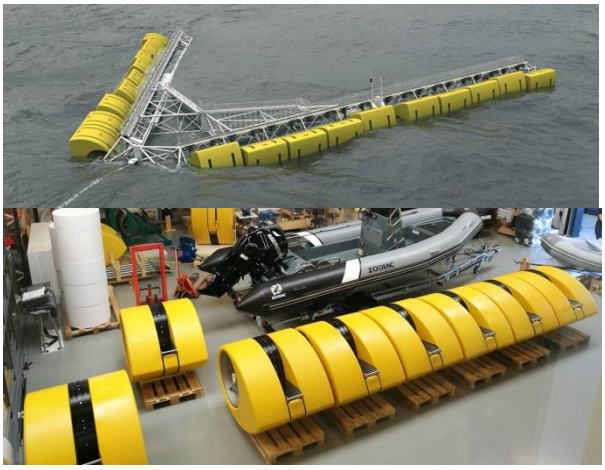
- Extend the COULWAVE boussinesq wave model with 2nd order generation
- Extend the COULWAVE boussinesq wave model to more than two vertical layers
- Speed optimizations of code (for example GPU support)
- Validate results by experiments in the new wave flume

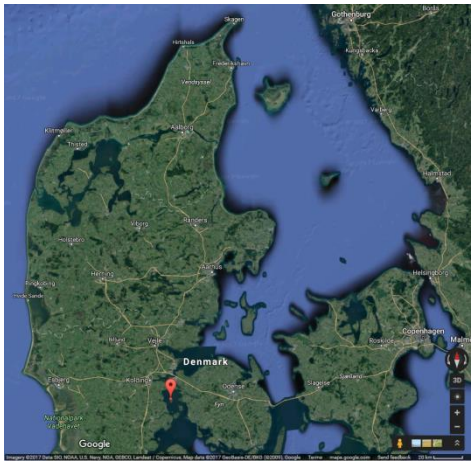
Contact persons: Mads Røge Eldrup, Thomas Lykke Andersen

Theory: ☒☒☒ **Experimental work:** ☒☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem:** ☐ **short master:** ☒ **Long master:** ☒

Analysis of performances of the Weptos wave energy converter

Purpose: The Weptos wave energy converter (WEC) is an A-shaped floating structure that absorbs wave energy through multiple wave absorbing bodies, the rotors. The prototype was launched in the spring of 2017, with a location in Lillebælt between Jylland and Fyn in Denmark, north of the small island Brandsø at a water depth of 10 m. The prototype with 20 approx. 1 m rotors is equipped with PLC control, a power-take of (PTO) drive train and electrical generators (2x 3 kW PMGs with back-to-back AC/DC/AC inverters). In addition to acquisition of the produced power of the PTO system at different stages of conversion, also the mooring force, the motion of the structure and the position of the opening angle is monitored and recorded continuously. For the characterization of the environmental conditions a TRIAXYS G3 Directional Wave Buoy was deployed. Sufficient data are gathered to enable evaluation of performance of the device and will be used in the current project for the analysis of performances of the Weptos prototype.





Main activities:

- Establishment of a database for the data acquired during the test campaign.
- Performance evaluation in terms of energy production and losses throughout the system.
- Evaluation of the performance of the mooring system. Validation of the initial mooring design.

Contact persons: Amélie Têtu, Jens Peter Kofoed

Theory: ☐☐☐ **Experimental work:** ☒☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☐ **short master:** ☒ **Long master** ☐

Control of the Weptos wave energy converter

Purpose: The development of the Weptos wave energy converter (WEC) is well under way with a machine being deployed in Lillebælt, Denmark. This system has so far been tested with simple control strategy and could gain in efficiency by developing a suitable control system. This control system will be composed out two parts: the adaption of the opening angle between the legs, which regulated the available incoming wave power, and the damping presented by the electrical generator system.

Main activities: The control system of renewable energy systems is not a new topic. However it has not been optimised yet for this particular application. Therefore first a thorough literature review has to be performed. Based on previous laboratory test results, smart control systems have to be presented. These can then be tested and further improved by performing experimental tests in the wave basin on real laboratory models.

Contact persons: Amélie Têtu, Jens Peter Kofoed

Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☐ **short master:** ☐ **Long master** ☒

Wave climate at the Nissum Bredning test site

Purpose: The purpose of the project is to define the wave climate at the Nissum Bredning test site. The test site is located south west from Aalborg and is run by DanWEC in close collaboration with AAU. The test site is equipped with a network of pressure sensors to measure the surface elevation and a wind sensor, giving both speed and direction of the wind.

The Nissum Bredning is situated in the western Limfjord at the Danish North Sea coast. Predominant west winds make this location suitable for testing scaled wave energy devices in real marine conditions. In order to effectively design the machine for a particular location, detailed wave conditions are required. The network of pressure sensors enables the establishment of the wave climate including directionality of the waves, which is valuable information for future developer interested in testing their device at the test site.

Main activities: The project will contribute to the on-going research on the subject and thus the following activities can be included:

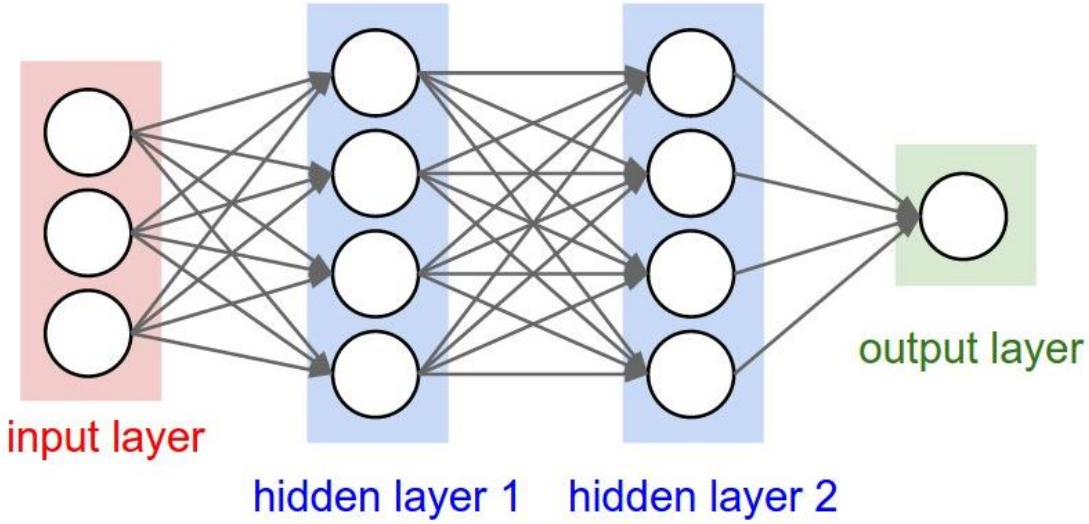
- Optimisation of the network sensor and gathering of data.
- Establishment of the wave climate at the test site based on the measurements including data quality control.
- Establishment of online monitoring of the wave climate

Contact persons: Amélie Têtu, Morten Kramer

Theory: ☒☐☐ **Experimental work:** ☒☐☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☐ **short master:** ☒ **Long master** ☐

Forecast of wave conditions at DanWEC test site

Purpose: Forecast of wave conditions is of primordial importance for planning installation, operation and maintenance of wave energy converters, which can account for more than 25% of the cost of energy. At DanWEC, the Danish test center for wave energy, a forecast model has been developed in collaboration with DHI group through an ongoing project. This model is run at DHI and is rendered available for DanWEC during the current project life time. In order to ensure that DanWEC has a reliable tool for predicting the wave climate at the test site, a forecast model needs to be developed. Autoregressive model or machine learning model are examples of models that could be developed for this purpose.



Main activities:

- Literature survey to give an overview of the different models that can be used for forecasting wave climate.
- Establishment of the model for forecasting wave climate at the test site.
- Establishment of online display of the wave climate forecast

The project will be connected to ongoing research projects.

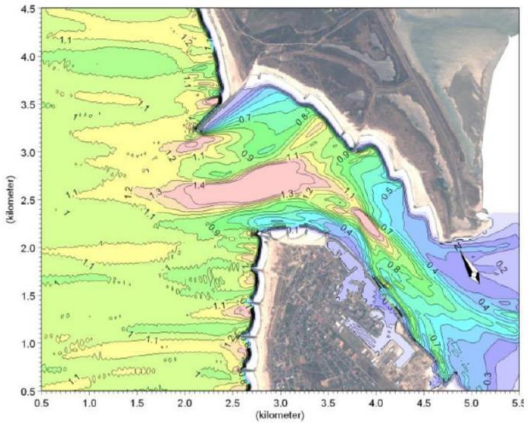
Contact persons: Amélie Têtu, Jens Peter Kofoed

Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☐ **short master:** ☐ **Long master** ☒

Evaluation of closing the Thyborøn Channel to reduce the coastal erosion at down drift beaches along the Danish West Coast

Purpose: Recent research has shown a potential for protecting the Limfjord against storm surges by installing a storm surge barrier in Thyborøn channel. The storm surge barrier can be closed temporarily during storms, which significantly reduce the extreme water levels in the fjord. The high flow velocities into the fjord during storms brings large amount of sediments into the fjord. The present situation is thus that the sediment, which accumulates inside the fjord, is missing in the sediment budget at the west coast, which results in erosion.

The purpose of this project is to use numerical models to analyse whether the storm surge barrier can have a positive effect on the coastal erosion at down drift beaches close to Thyborøn channel, since the flow into the fjord will be much less and thus a much smaller part of the long-shore sediment transport at the west coast is expected to enter into the Limfjord. For the study, there is an opportunity for cooperation with the Danish Coastal Authority.



Main activities: The project will contribute to the on-going research on the subject and thus the following activities can be included:

- Evaluation of the processes leading to coastal erosion near the Thyborøn channel
- Numerical modelling of the influence of closing Thyborøn channel during storm on the coastal erosion at neighbouring beaches

Contact persons: Jørgen Quvang Harck Nørgaard, Thomas Lykke Andersen

Theory: ☒☒☐ Experimental work: ☐☐☐ Computer modelling: ☒☒☒
Suitable project type(s): 3rd sem ☐ short master: ☒ Long master ☒

Understanding the erosion affecting Danish Coast

Purpose: Some parts of the West coast of Denmark suffer from severe erosion and longshore transport is consistent. Nørlev Strand, a small village in the North-West coast of Denmark, in Hjørring Kommune, has been in the center of a dispute, because coastal erosion here is making houses fall into the water. Some claim the fault of the erosion is directly related to costal protection works realized few kilometers south. What is part of the natural evolution of the coastline and what is caused or accelerated by men intervention? Answering this question is necessary in order to attribute responsibilities and find a solution to the problem.

Main activities: Depending on the interest of the students, the project could be completely numerical (MIKE 21 software), or the numerical part could be implemented by experimental investigation (Hydraulic and Coastal Engineering Laboratory). The analysis can be limited to few kilometres of coastline or extended to a wider area.

- Numerical simulations describing and predicting coastal evolution under the influence of waves and currents
- Investigation of coastal protection solutions (numerical and/or experimental analysis)
- More holistic approaches that include cost calculations and cost/benefit analysis are also encouraged.

Contact persons: Lucia Margheritini

Theory: ☒☐☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☐ **short master:** ☒ **Long master** ☒

Stability of coastal slopes

Purpose: Erosion of the west coast of Denmark is an increasing problem, which has become more critical then ever before. This project deals with the stability of the near costal slopes. During the project the effect on the stability of errosion of the toe of the slope and that waterflow through the slope is studied.

Main activities: The project will contribute to the on-going research on the subject and thus the following activities can be included:

- State of the art study
- Case study on the influence on climate change at specific site
- Case study on the influence on sediment transport at specific site
- Theoretical assessment of slope stability

Contact persons:
Benjaminn Nordahl Nielsen, Søren Dam Nielsen, Rikke Holmsgaard

Theory: ☒☒☒ **Experimental work:** ☒☐☐ **Computer modelling:** ☒☒☐
Suitable project type(**s**): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Alternative materials for the third Limfjord crossing

Purpose: One of the major challenges in connection with the construction of a 3rd Limfjord crossing is the lack of suitable materials for highway building.

Normally are used large quantities of sand and gravel to such a project. However, these materials are no longer available in the desired quantities in North Jutland. Therefore, there is a need for alternatives to the traditional materials and methods of hignway building.

Main activities: The project is relatively open with concern to the problem to be analysed and can include:

- State of the art study
- Case study of soil parameters
- Different foundation solutions
- Laboratory Tests

Contact persons:
Benjaminn Nordahl Nielsen, Søren Dam Nielsen, Rikke Holmsgaard

Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

New method for soil compaction

Purpose: To develop new methods for compacting sand in the laboratory and possibly also the field.

Currently, different methods are used for compaction of sands. In the laboratory e_{max} and e_{min} (Relative density) is measured using a stamping method, and for model testing the soil is being compacted using rod vibrators, giving a possibly variating compaction. In the field, sand is compacted using a vibrating plate compactor. All methods however are time-consuming since they are performed manual.

Main activities: The project is relatively open with concern to the problem to be analysed and can include:

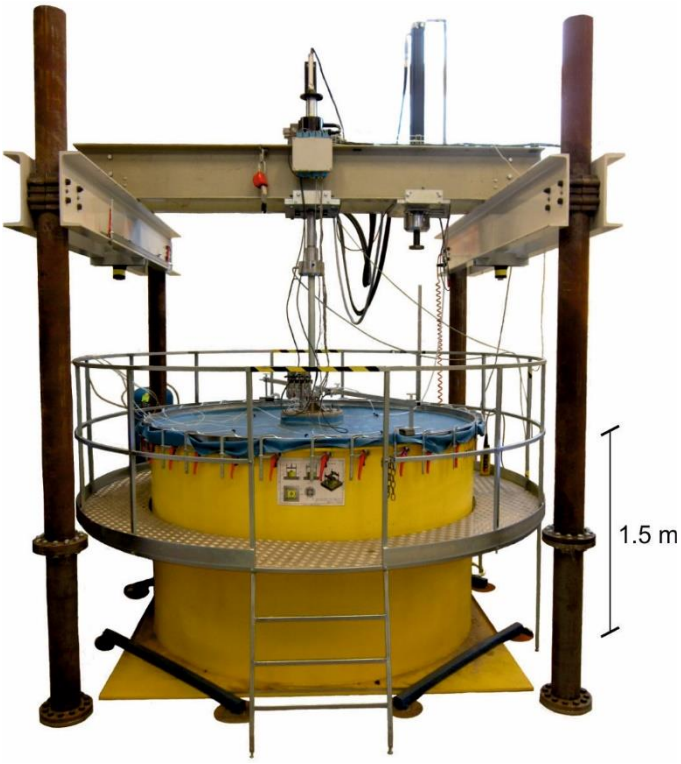
- State of the art study
- Laboratory Tests
- Field testing
- Reliability
- Design model creation / best practise.

It may be possible to co-operate with Department of Mechanical and Manufacturing Engineering as regards to designing a robot that are able to perform the compaction.

Contact persons: Benjaminn Nordahl Nielsen, Rikke Holmsgaard, Søren D. Nielsen
Theory: ☒☒☐ **Experimental work:** ☒☒☒ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Design of indoor test facilities

Purpose: Take part in designing our new indoor test facility/sandbox that will be used for model testing.



Main activities: The project will contribute to the on-going research on the subject and thus the following activities can be included:

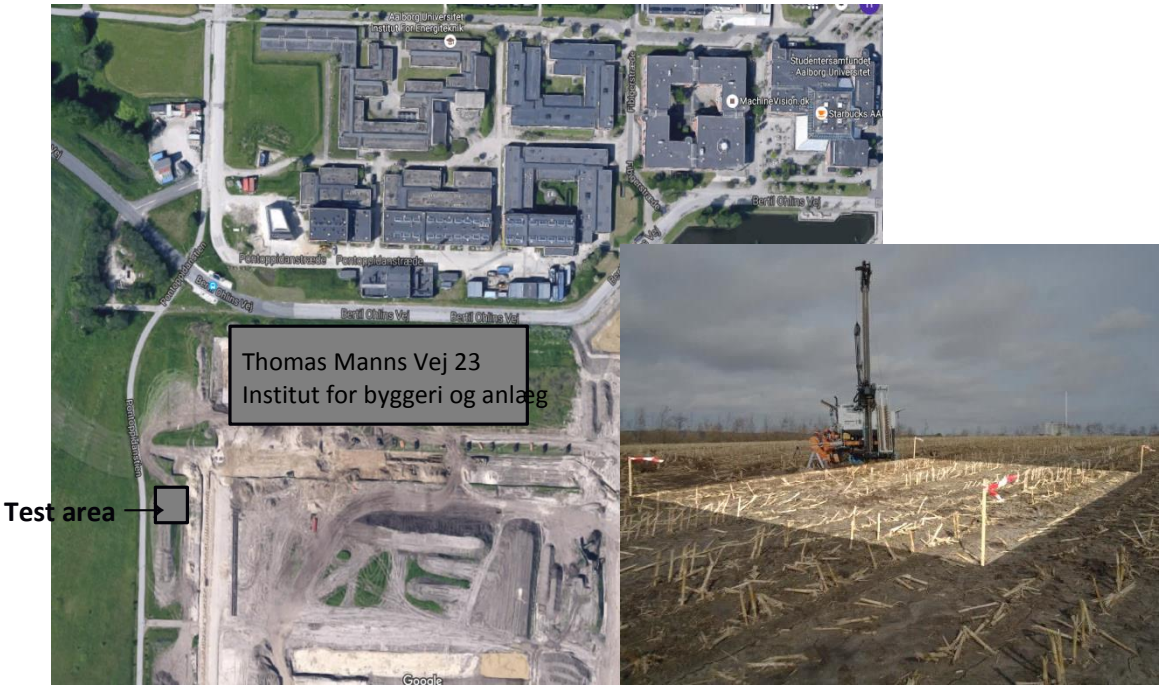
- State of the art
- Boundary conditions
- Sand behaviour at low stress levels
- How to control the water level
- How to prepare and compact the sand in the box
- Numerical models of which foundations models that could be examined in the sand box

Contact persons:
Benjaminn Nordahl Nielsen, Søren Dam Nielsen, Rikke Holmsgaard

Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Design of outdoor test facilities

Purpose: Take part in designing our new outdoor test facility that should be used for designing climate roads and development of CPT correlations.



Main activities: The project will contribute to the on-going research on the subject and thus the following activities can be included:

- State of the art
- Boundary conditions
- Size, depth and excavation of the test area
- Sand behaviour at low stress levels
- How to control the water level
- How to prepare and compact the soil at the test site
- Numerical models of which foundations models that could be examined

Contact persons:
Benjaminn Nordahl Nielsen, Søren Dam Nielsen, Rikke Holmsgaard

Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Electric vane test

Purpose: Contribute to the geotechnical society by using the new electric vane test in order to examine the reliability and application of the vane test.

The vane test is a highly used in situ test method. In Denmark the vane test is applied in almost all projects, but recently, geotechnical engineers are questioning whether or not the vane test result are sufficiently reliable. This is partly because the vane tests are not conducted with enough consistency and the correlation between vane results and undrained shear strength (especially in organic soils) are not evident. By applying a new electric vane test, which should be less operator dependent new investigations can commence. Find the presentation from the DGF meeting concerning the vane tests:
http://www.danskgeotekniskforening.dk/sites/default/files/pdf/pdf2017/Moede%201.%202017/JDA%20-%20In%20situ-styrkem%C3%A5ling%20i%20organiskholdig%20jord.pdf

A project with GEO SUBSURFACE EXPERTISE

Main activities: The project will contribute to the on-going research on the subject and thus the following activities can be included:

- State of the art study
- Field and laboratory Tests
- Interpretation of data
- Reliability
- Theoretical assessment

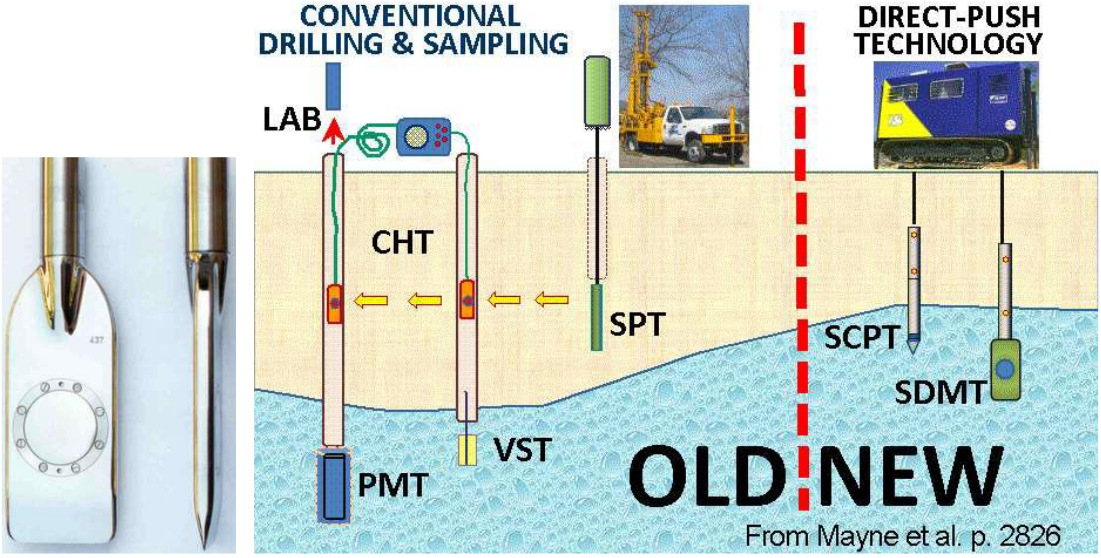
Contact persons: Rikke Holmsgaard, Benjaminn Nordahl Nielsen, Søren D. Nielsen

Theory: ☒☒☐ **Experimental work:** ☒☒☒ **Computer modelling:** ☒☐☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Rock the soil: SDMT Flat Dilatometer

Purpose: Try the new in-situ soil testing. The SDMT (seismic) Flat Dilatometer offers measuring / interpretation of a series of soil parameters by direct-push technology (M, c_u, K_o, OCR, φ, γ).

Aalborg University has the first SDMT equipment in Denmark.



Main activities: The project will contribute to the introduction of the DMT and SDMT technology in Danish soils. The activities will include:

- Setup of equipment
- Interpretation of data
- Field and laboratory Tests
- Theoretical assessment
- Best practise.

It may be possible to perform experimental field tests together with external company.

Contact persons: Benjaminn Nordahl Nielsen, Rikke Holmsgaard, Søren D. Nielsen, Lars Bo Ibsen

Theory: ☒☒☐ **Experimental work:** ☒☒☒ **Computer modelling:** ☒☐☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Be the first to try the new CPT rig

Purpose: Be the first to try the new CPT rig and contribute to the geotechnical society by developing new approaches to determine soil strength parameters from CPT.

Today the Cone Penetration Test (CPT) is increasingly being applied to geotechnical projects. Still, there exist no uniform methods on how to interpret strength parameters from the CPT measurements. Aalborg University has ordered a new CPT rig, which makes it possible to conduct CPTs and collect undisturbed soil samples at places where it is impossible for other boring rigs. Watch the CPT rig at https://www.youtube.com/watch?v=zf_eRpbo1C0

Main activities: The project will contribute to the on-going research on the subject and thus the following activities can be included:

- State of the art study
- Setup of equipment
- Field and laboratory Tests
- Interpretation of data
- Theoretical assessment

Contact persons: Rikke Holmsgaard, Benjaminn Nordahl Nielsen, Søren D. Nielsen

Theory: ☒☒☐ **Experimental work:** ☒☒☒ **Computer modelling:** ☒☐☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Aalborg Clay

Purpose: To improve the knowledge about soil parameters for late glacial clay

In connection with the "Musikhuskvarteret" a number of borings have been performed taking undisturbed samples in "Aalborg Clay" for laboratory testing in this project. CPT's and in situ testing make it possible to setup new interpretations of soil parameters.

Main activities: The project will contribute to the ongoing understanding of Danish late glacial clay soils.

The activities will include:

- Consolidation tests
- Triaxial tests
- Bender tests
- Using CPT and in situ testing
- Theoretical assessment

Contact persons: Benjaminn Nordahl Nielsen, Rikke Holmsgaard, Søren D. Nielsen

Theory: ☒☒☐ **Experimental work:** ☒☒☒ **Computer modelling:** ☒☐☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Determination of small-strain stiffness of soils

Purpose: There are several measures of the stiffness of soils. These stiffness's are not only stress dependant, they are also strain dependant. In dynamic geotechnical problems, the strain levels are usually very small. Hence, the soil will have a relative high stiffness. The small strain shear modulus (G_{max}) can be determined using Bender Elements. This project will focus on how to use Bender Elements for measuring the small strain shear modulus of soils.

Main activities: The project can include:

- Introduction to bender elements
- Gathering and analysis of current design material
- Laboratory tests and theoretical assessment
- Computational modelling
- Design model creation.

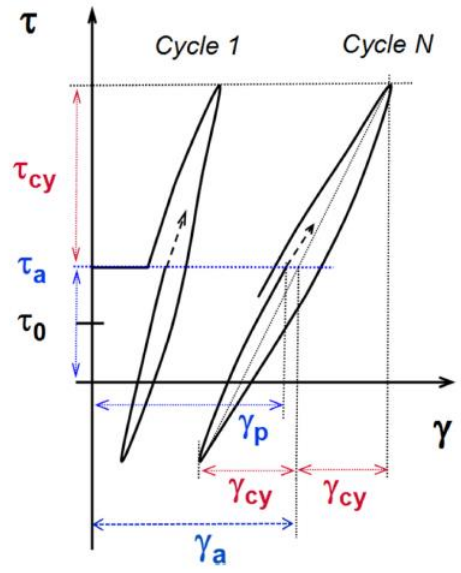
Part of the project may be carried out together with geotechnical firms taking soil samples and making input for actual design problems.

Contact persons: Søren Dam Nielsen, Benjamin N. Nielsen, Rikke Holmsgaard

Theory: ☒☒☐ **Experimental work:** ☒☒☒ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Cyclic Behaviour of Soil

Purpose: Offshore structures are exposed to cyclic loading, mainly from wind and waves. Therefore, the soil surrounding the foundation will experience cyclic loading as well. Cyclic soil behaviour is very complex and both strength and deformation parameters may change with cyclic loading. How they change depends on the nature of the cyclic load in terms of: load frequency, load amplitude and mean value. Even though research on the field has been carried out for the last 20 years, there is still no standardised guideline on how to predict the soil response from cyclic loading.



Main activities: The project will contribute to the on-going research on the subject and thus the following activities can be included:

- Literature study on soil behaviour due to cyclic loading.
- Performing cyclic triaxial tests.
- Calibrate one or more existing models to predict cyclic load effects.
- Develop new models to predict cyclic load effects.

Contact persons: Søren Dam Nielsen, Benjaminn N. Nielsen, Rikke Holmsgaard

Theory: ☒☒☐ **Experimental work:** ☒☒☒ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☐ **short master:** ☒ **Long master** ☒

Let's make the Limfjords tunnel great again!
Wanted: rescue plan

A project with:

Vejdirektoratet

Purpose: Despite expensive repairs, threatening settlements continue at Limfjord tunnel. The tunnel has been leaking virtually since its opening. If the tunnel is to be in service for the 80 years it was originally designed for, new ideas must be put on the table.

Limfjord tunnel consists of a 510 m long tunnel. The tunnel consist of elements, 102 m long, cast of seven 12.8 m long sections. Since messurements was started settlements of 13 cm have been recorded, up to 1 cm per year.

Main activities: The project will contribute to an idea competition and workshop the Danish road Directorate is organizing in 2017. The following activities can be included:

- Experimental and/or numerical modelling of settlements
- Case study of soil parameters
- Case study of foundation solutions
- Prediction of future settlements

Contact persons:
Benjaminn Nordahl Nielsen, Lars Bo Ibsen, Søren Dam Nielsen, Rikke Holmsgaard

Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Development of driveability model for piles for offshore wind turbines

A project with COWI

Purpose: An increased focus on renewables in general has ignited a spark in market for offshore wind turbines. The industry has a joint mission to lower the cost of energy from offshore wind turbines to make the solutions more competitive in the open energy market. The installation of piled foundations for offshore wind turbines is today governed by qualified guessing, since soil conditions may vary greatly throughout an offshore wind farm. The ability to predict and complete the driving campaign as effortlessly as possible is more often than not a project deal-breaker.

Up-close of installation of offshore piles (www.4coffshore.com).

A vessel used for installation of piles for offshore wind turbines (www.cape-holland.com).

Main activities: The project seeks to develop a method for accurate driveability predictions based primarily on theoretical considerations and back-calculation of driving logs from real-life installation of piles for offshore wind. The method will be based on existing methods, which are validated and subsequently modified through calibration:

- Assess state-of-the-art research and methodology within the area of offshore driveability and understand the basic physical and theoretical principles involved in the driving of large-diameter piles.
- Based on available driving data from installed piles, complete back-calculation in order to validate existing methods.
- Based on existing methods and available data for back-calculation, develop a theoretically founded method for robust and accurate driveability predictions for various ground conditions.

Contact persons: Martin Underlin Østergaard (muoe@cowi.dk), Lars Vabbersgaard Andersen (la@civil.aau.dk)

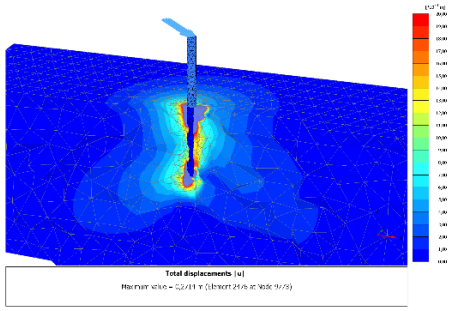
Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Dynamic analysis of monopiles for offshore wind

A project with COWI

Purpose: When designing foundation structures for offshore wind turbines, the dynamic performance of the structure, regularly characterized by the eigenfrequency, is often driving the design due to fatigue loading. Through measurements on foundation structures, e.g. monopiles, with operating wind turbines, it is possible to assess the dynamic performance and compare to the design. In order to optimize the design of a monopile, the dynamic performance must be estimated as close to reality as possible. The dynamic performance is strongly influenced by the stiffness of the pile-soil interaction; hence, the ability to predict the correct pile-soil stiffness for use in dynamic analyses is paramount.

Installation of a wind turbine on a monopile (www.4coffshore.com).



Finite element modelling of a monopile.

Main activities: The project seeks to improve existing and develop new methods for estimating pile-soil stiffness for use in dynamic analyses through theoretical considerations and back-calculation of real-life measurements, ultimately developing a robust model for estimating the eigenfrequency of the as-built monopile:

- Understand the basic physical and theoretical principles involved in the estimation of eigenfrequencies for monopiles.
- Develop a simple model to assess the eigenfrequency to understand and quantify the impact of the pile-soil stiffness.
- Based on available data from installed offshore wind farms, complete back-calculation using available 1D methods for estimating pile-soil stiffness and if possible improve existing or develop new methods for this purpose.
- Using finite element modelling, estimate the dynamic performance and compare to examined 1D methods and in-situ measurements.

Contact persons: Martin Underlin Østergaard (muoe@cowi.com), Lars Vabbersgaard Andersen (la@civil.aau.dk)

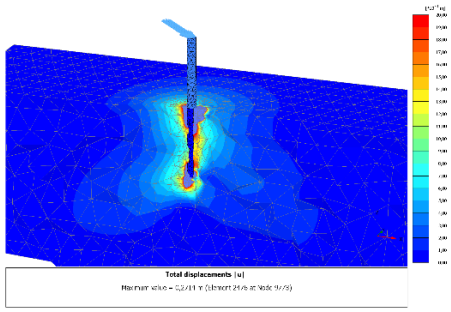
Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Development of best practice for finite element modelling of monopiles for offshore wind

A project with COWI

Purpose: Due to a strong demand for optimization of the foundation structures for offshore wind turbines, new tools are incorporated in the design process, and finite element (FE) modelling has become increasingly important. As for all FE models, the quality of the output is dependent solely on the quality of the input and the model setup. Since the use of FE modelling for offshore wind is relatively new, a so called "best practice" has not yet been developed. However, the recent investigations done in connection to the DONG-led PISA-project has provided a useful basis for developing best practices.

Sketch drawing of a monopile.



Finite element modelling of a monopile.

Main activities: The project aims at developing a best practice for FE modelling of foundation structures for offshore wind through considerations regarding theoretical soil behaviour and available constitutive models as well sensitivity analyses of input:

- Understand and establish the basic parameters for FE modeling of foundations as well as the individual importance of these.
- Develop FE model and compare total pile response to that obtained from simpler models, e.g. Winkler-models using various p-y formulations.
- Compare FE model to pile load test results and perform calibration and assessment of chosen constitutive model.
- Based on assessment of suitability of various constitutive models as well as elasticity of input parameters and experience regarding model setup, develop a best practice for FE modelling of offshore foundation structures.

Contact persons: Martin Underlin Østergaard (muoe@cowi.com), Johan Clausen (jc@civil.aau.dk)

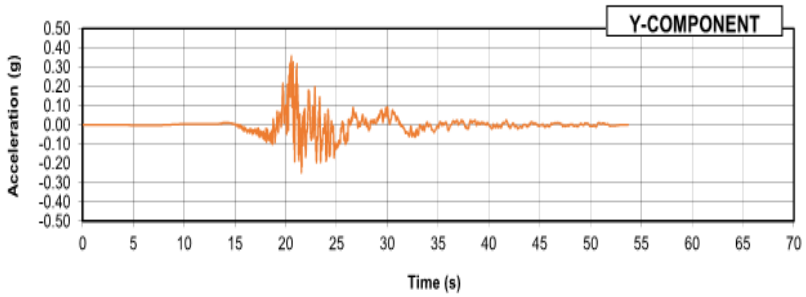
Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Earthquake design of monopiles

A project with COWI

Purpose: The offshore wind farms are moving to new regions, and new design scenarios are continuously introduced due to shifts in environmental climate and loading. Especially the Asian market for offshore wind is growing rapidly and natural hazards, like earthquakes, need to be accounted for to a much greater extent compared to e.g. European wind farms. Depending on the soil conditions, an earthquake can have a large impact on the structure, through e.g. liquefaction of the supporting soil and kinematic soil-structure interactions. This impact needs to be accounted for in the design.

Sketch of a monopile.



Example of acceleration time series from earthquake.

Main activities: The project aims at investigating available methods for aiding the design of monopiles for the offshore wind industry placed in regions with frequently occurring earthquakes. The following items can be considered in this investigation:

- Understand the concept of soil liquefaction and other earthquake-induced impacts on design of monopiles.
- Conduct literature review and develop a state-of-the-art of existing methods (e.g. based on p-y springs) for accounting for liquefied soil in design of laterally loaded piles.
- Develop a Winkler-based tool to assess the impact of different methods for accounting for liquefied soil.
- Using commercial software, like e.g. PLAXIS, FLAC or LPILE, conduct an assessment of the laterally loaded pile accounting for relative deformation between soil and pile caused by movement of the soil volume.

Contact persons: Martin Underlin Østergaard (muoe@cowi.dk), Lars Vabbersgaard Andersen (la@civil.aau.dk)

Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Offshore wind suction bucket on an industrial scale

Purpose: The project aims to develop a modular suction bucket design to the Siemens jacket concept for a +10 MW turbine. Objectives have been to create a modular bucket where modules can be produced in existing industrial manufacturing facility. In this project the aim is to demonstrate install-ability and in-place capabilities of design in laboratory environment.

Foundation costs of offshore wind including production and installation represent 20-30% of the total costs of deploying an offshore wind park. Lowering costs of foundations is a key element to lower the total Levelized Cost of Energy (LCoE) for offshore wind. Suction buckets are one of the most promising seabed interfaces technologies in the industry.

Main activities: The project will focus on developing a working framework for the design of suction anchors used for the offshore wind industry, covering subjects such as, but not limited to:

Siemens Jacket concept for +10 MW wind turbine.

- Installation of suction anchors using pressure and the challenges associated with this in various types of soil.
- The tensile and compressive capacity considering loading direction, loading rate and cyclic loading that are comparable to an offshore storm event.
- Laboratory testing to assess the impact of various types of loading (e.g. cyclic) to a typical offshore soil and the soil mechanics involved.
- Small-scale testing to assess the behaviour of the suction caisson/anchor during different loading and soil conditions.

The Project will be in close corporation with Siemens Wind Power and Universal Foundation A/S

Contact persons: Lars Bo Ibsen (lbi@civil.aau.dk)

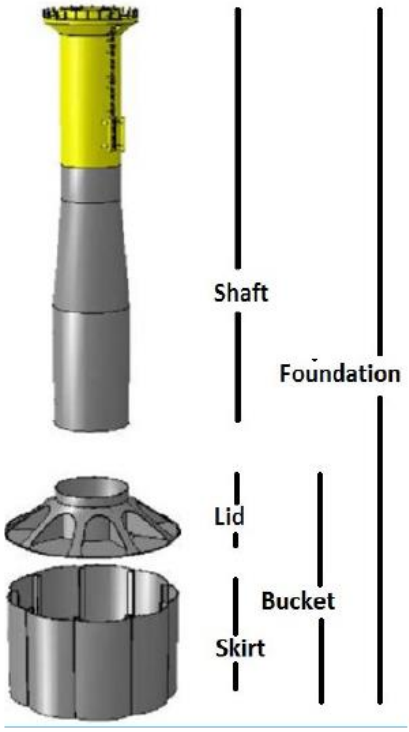
Theory: ☒☒☒ **Experimental work:**. ☒☒☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Develop a new mono – bucket for a +10 MW wind turbine

Purpose: The project aims to develop a modular mono bucket design for a +10 MW turbine. Objectives are:

1. Create a modular bucket where modules can be produced in existing industrial manufacturing.
2. Demonstrate install-ability and in-place capabilities of design in laboratory environment.

Foundation costs of offshore wind including production and installation represent 20-30% of the total costs of deploying an offshore wind park. Lowering costs of foundations is a key element to lower the total Levelized Cost of Energy (LCoE) for offshore wind. Suction buckets are one of the most promising seabed interfaces technologies in the industry.



Main activities: The project will focus on developing a working framework for the design of the mono bucket used for the offshore wind industry covering subjects such as, but not limited to:

Installation of suction anchors using pressure and the challenges associated with this in various types of soil.

Bearing capacity considering loading direction, loading rate and cyclic loading that are comparable to an offshore storm event.

Laboratory testing to assess the impact of various types of loading (e.g. cyclic) to a typical offshore soil and the soil mechanics involved.

Small-scale testing to assess the behaviour of the mono bucket during different loading and soil conditions.

The Project will be in close corporation with Universal Foundation.

Contact persons: Lars Bo Ibsen (lbi@civil.aau.dk)

Theory: ☒☒☒ **Experimental work:**. ☒☒☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Comparison of Finite Element calculations for geotechnical cases

Purpose: Many finite element software packages that are used for geotechnically related computations exist. Some are specialized for geotechnical problems and others are general purpose programs. Even though the initial problem is well defined, e.g. a surface footing on a Mohr-Coulomb soil, different programs can arrive at different solutions for the sought-after results, be they stresses, displacements or bearing capacity. This can be due to, for example, variations in the numerical implementation, or different formulations of the material models.

If these variations in the results are significant, it poses a problem for the design engineer who relies on the solutions of the chosen software: What is the correct solution?

The idea of this project is to examine the variations between different tools for solving geotechnical problems, both qualitatively and quantitatively.

Main activities: One or more geotechnical calculation cases should be chosen. Ideally one of them with a known solution to which numerical results can be compared. Then the problems are modelled using different numerical tools, of which some relevant examples can be seen in the above figure. Inhouse codes, e.g. written in MatLab, can also be used. The calculation cases should range from a simple bearing capacity calculation to some problems with higher complexity according to the interest of the student and capabilities of the chosen software packages. Examples are: Advanced constitutive models, seepage, consolidation, interface elements, staged construction, slope stability.

Contact person: Johan Clausen, Lars V. Andersen

Theory: ☒☐☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☐

Improved FEM-modeling of non-associated plasticity

Purpose: The most common material model for soils is the Mohr-Coulomb model where the soil strength is controlled by the cohesion and the friction angle. The deformation during plastic flow is controlled by the dilation angle. When the model is associated, i.e. friction angle = dilation angle, reliable calculation methods are abundant both in the elasto-plastic as well as the rigid-plastic case. Experimental observations, however, predicts that the dilation angle should be much lower (often ~30°) than the friction angle. Unfortunately, this causes a lot of computational problems. Random errors seem to occur and simulations break down.

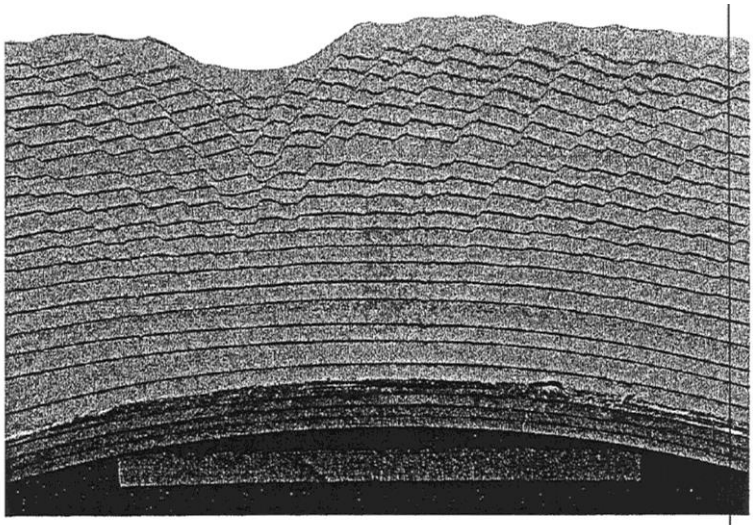


Fig. 8.2 Crestal faults over arch of uniform curvature, simulated in a sand box (Mandl, 1984).

In this project, the goal is two-fold: 1) The influence of non-associated plasticity on e.g. bearing capacities should be quantified. This is very relevant, as design codes, e.g. the EuroCode base the design formulae on associated plasticity. 2) Examination on how different methods can be used to run finite element analyses using non-associated material models.

Examples of main activities:

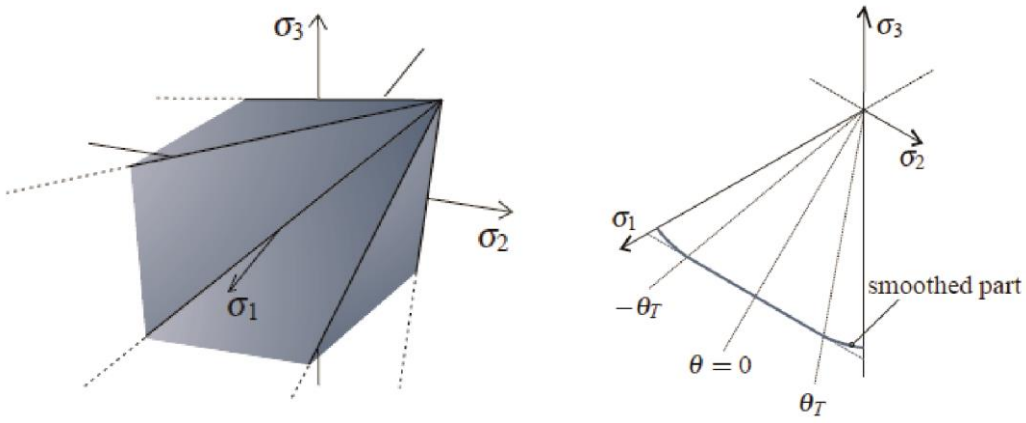
- What are the symptoms of non-associated problems? A computational and literature review.
- What do the commercial codes do (e.g. Abaqus, Plaxis, Optum2G)?
- Do we have other methods of remediating the problem?
- Quantification of different results with different methods

Contact person: Johan Clausen

Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Implementation of a plasticity model into the finite element method 1: Rounded Mohr-Coulomb

Purpose: The most often used material model for geotechnical materials is the Mohr-Coulomb material model. For calculation involving more than very simple geometries the finite element method is used for obtaining the solutions to the arising boundary value problems (i.e. load-displacement curves, bearing capacities, etc.). Originally, the corners and the apex of the Mohr-Coulomb yield surface caused problems in the numerical implementation, so an approximate yield surface with smoothed, or rounded, corners were used. Today methods for implementing the corners explicitly exist, but the use of the rounded surfaces is still widespread. The implications of using these approximations, however, are not documented in literature.



Main activities: Different models for smoothing the Mohr-Coulomb model should be implemented, and maybe also as a user programmable material in Abaqus. Then the implications of using these approximate models should be quantified and compared to the exact Mohr-Coulomb material model. Both with respect to accuracy, computation time and number of iterations. The approximate models may perform better than the exact model in some parameter combinations and poorer in others.

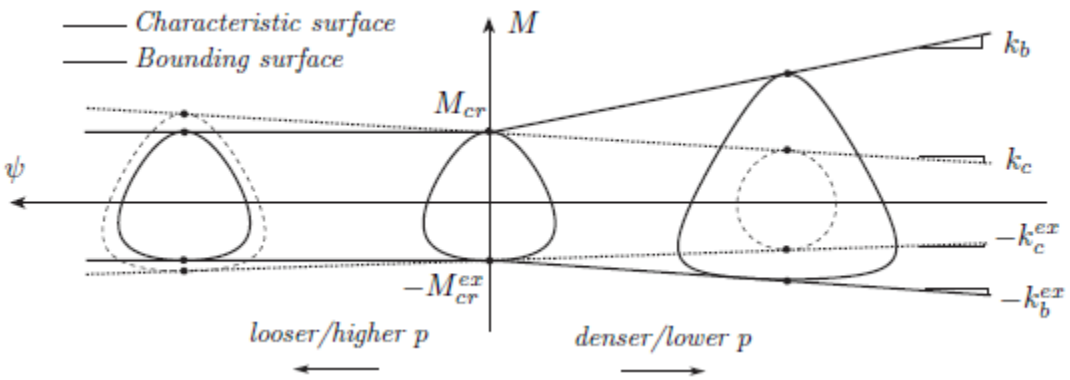
An interest in programming, e.g. MatLab, is essential.

Contact person: Johan Clausen

Theory: ☒☐☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Implementation of a plasticity model into the finite element method 2: A two-surface model for cyclic loading on sand

Purpose: For strength calculations the Mohr-Coulomb criterion is often a sufficient material model for soils. If a more precise calculation of the deformation is needed then the simple linearly elastic – perfectly plastic Mohr-Coulomb model is not adequate. This is especially true if the loading is not monotonic or even cyclic. Offshore structures are subjected to time varying loads from wind and waves, which means that their foundation will experience cyclic loading. At the same time, the allowable deformation is small which means that it is often this criterion rather than the soil strength that governs the foundation design. For these reasons many advanced material models for soils have been developed. If such an advanced model is to be used in practical calculations it must be implemented in a numerical method, e.g. the finite element method.



Main activities: Earlier projects have been working with the implementation of the above mentioned model into the finite element method. This project should be a further development of this. The activities could be improvement of the algorithms, implementation of the model as a user-defined model in e.g. Plaxis and/or Abaqus and case studies on structures under cyclic loading.

An interest in programming, e.g. MatLab, is essential.

Contact person: Johan Clausen

Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Implementation of a plasticity model into the finite element method 3: The Plaxis Hardening Soil model

Purpose: For strength calculations the Mohr-Coulomb criterion is often a sufficient material model for soils. If a more precise calculation of the deformation is needed then the simple linearly elastic – perfectly plastic Mohr-Coulomb model is not adequate. For this reason, various advanced constitutive models for soils have been developed over time, with the aim of correctly modelling the total stress-strain path of the soil, in order to be able to accurately predict the displacement of geotechnical structures in the service limit state. Probably the most popular advanced soil model for practical use is the so-called Hardening Soil model. Its popularity is probably due to two reasons: 1) It is available in the popular geotechnical software Plaxis 2) the model parameters include the Mohr-Coulomb parameters together with some stiffness parameters, which are fairly easy to obtain from laboratory testing. As of yet the model is not available in other software codes. Therefore, the goal of this project is to implement the hardening soil model in an in-house finite element code and possibly export it as a user material into Abaqus.

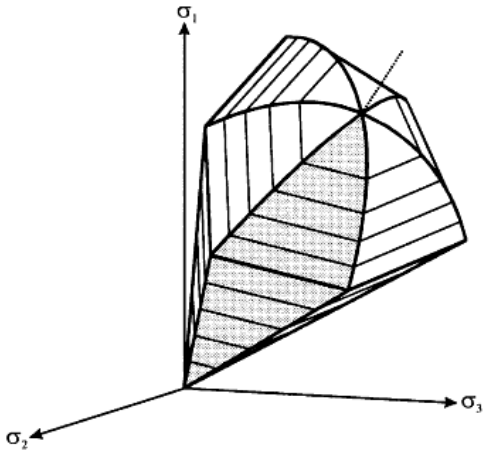


Figure 3. Representation of total yield contour of the Hardening-Soil model in principal stress space for cohesionless soil.

Main activities: The main activity of the project would be to study and implement the Hardening Soil model into a finite element program, and compare results with e.g. results from Plaxis.

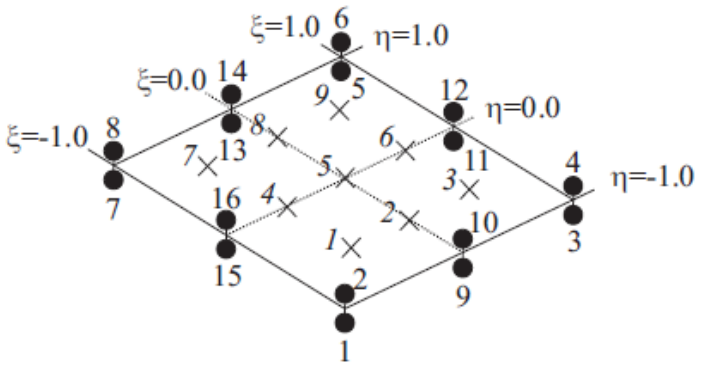
An interest in programming, e.g. MatLab, is essential.

Contact person: Johan Clausen

Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Implementation of interface friction finite elements

Purpose: When designing geotechnical structures, the interaction between the soil and the structures, e.g. footings or walls can have a significant impact on the displacement and strength on the overall structure. The interaction can consist of both adhesion and friction. In finite element analyses, the interaction can be modelled with so-called interface elements, as it is seen in e.g. the commercial code Plaxis, from the manual of which, the figure below is taken. Several methods of implementing interaction elements exist. The goal of this project is to implement interaction elements in a finite element code in MatLab.



Local numbering and positioning of nodes (•) and integration points (x) of a 16-node interface element

Main activities: Firstly, a litterature study on interface finite elements should be carried out. Then one or more types of interface elements should be implemented into a finite element code. The performance of the elements should be compared to existing solutions, e.g. strip footing bearing capacities, where exact solutions are known for different degrees of footing roughness. Other case studies can be carried out, e.g. quantifying the effect of the degree of roughness of sheet pile walls.

If time permits, the work can be extended to three-dimensional finite elements.

Contact person: Johan Clausen

Theory: ☒☒☐ **Experimental work:**. ☐☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Environmental vibration and noise

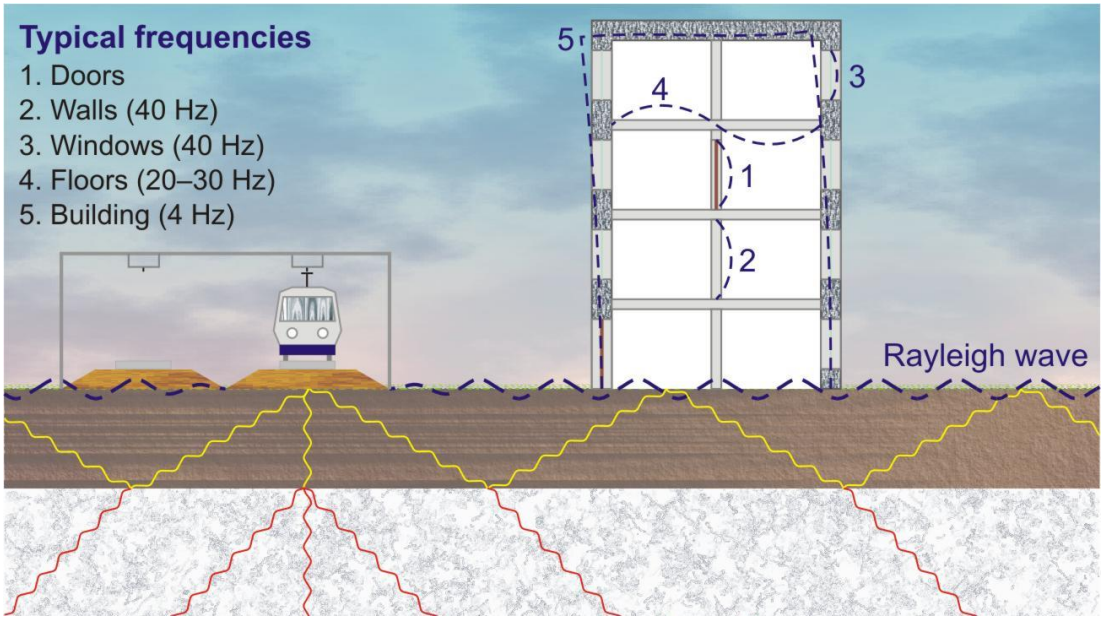
Large cities have many advantages. Less distance between home, work, shopping, culture, etc., reduces traffic. This saves time for the individual and has less impact on the environment, but it comes at a cost. Urban air pollution has long been in focus; but there is a growing understanding that another major problem is related to noise and vibration. For example, traffic caused less than 200 casualties in Denmark in 2015—but about 500 people died as result of long-term exposure to traffic noise!

Problems relating to sound and vibration can typically be analysed as a combination or a *source*, e.g. a train, a *transmission path*, e.g. soil and building, and a *receiver*, e.g. the sound field and eventually the human beings in a room. To obtain good solutions and engineering designs, the analyst must have a good understanding of the various parts of the problem. This understanding can be reached via theoretical studies, measurement and modelling.

On the next pages, a number of project ideas are proposed. The common topic is vibration and noise, and some of the projects are done in close collaboration with companies or researchers from other institutions. The possibilities are plentiful for doing short or long master thesis focussing on computational modelling, field measurements, laboratory measurements, or a combination.

For the master thesis, a group size of two to three students is preferred. However, all projects are scalable and can be adjusted to fit the number of students and number of ECTS. Further, it is possible to do the projects marked “Fit for 3rd semester project” as a 15 ECTS project in a group of 3 to 5 students as well.

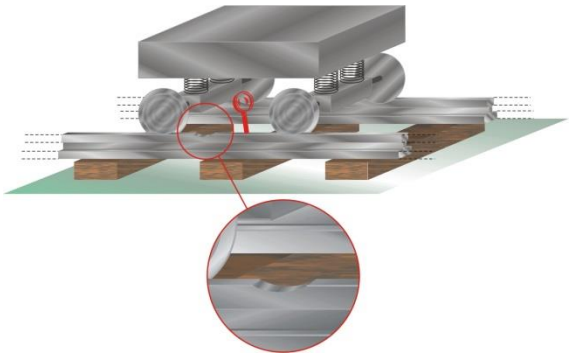
Contact person: Lars V. Andersen



Vibrations induced by traffic or construction work

Purpose: Traffic on roads and railways is a common source to vibrations that may cause annoyance to people in the built environment. Current design regulations provide limited information about design criteria, and valid models for prediction of vibration levels are generally not available. Usually, vibration levels are measured on "similar" roads or railway tracks, and in similar building structures, and an empirical model is employed for prediction of vibrations in a new building project. Prediction tools for vibration caused by construction work, e.g. sheet pile driving, are at an even earlier stage in development.

Hence, better prediction tools are required, and the idea of this project is to develop a method based on computer modelling. The model should include the source, the subsoil and the building. The general idea is to determine the significance of different parameters, e.g., soil properties, vehicle type, building material or road irregularity, on the vibration levels observed by people in a building. For example, the focus of the project can be design and analysis of road humps or prediction of vibrations from pile driving. The project will be carried out in collaboration with COWI A/S.



Main activities: A coupled model consisting of the source (vehicle and track or pile), subsoil and building can be made in a commercial finite-element analysis program (e.g., ABAQUS or COMSOL) or, preferably, a MATLAB code may be developed for the purpose. In either case, some of the following items will be part of the project work:

- Literature study of vehicle dynamics or pile driving
- Literature study of wave propagation in soil and building structures
- Numerical modelling of vibration transmission through ground and structure
- Modelling of a lorry, bus or train, or a pile including the load from the hammer
- Modelling of road or track surface irregularities (e.g. a road hump), or pile driving
- Parameter studies for various vehicles, tracks, piles, soils and/or buildings
- Experimental validation of the model in the field or in the laboratory.

Contact person: Lars V. Andersen **Fit for 3rd semester project:** ☒

Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐

Monitoring transition zones with embedded sensing

Purpose: In many situations the structure or subgrade (or both) of a railway pavement are abruptly varied in the longitudinal (travel) direction. This is the case, for example, in bridge approaches, railroad crossings, and when passing over buried installations or utilities. The term “transition-zone” refers to a railway section that is close to, and affected by, the sharp change in pavement layering. Practical experience has shown that transition-zones exhibit amplified degradation rates and therefore demand more maintenance attention. Characteristic distress modes include large resilient settlements, permanent elevation/geometry changes, ballast degradation, and tie-ballast gaps.

The overall goal of this project is to evaluate a new approach for monitoring the condition of transition-zones. The idea calls for embedding a cluster of inertial sensors inside the railway pavement system. Sensor burial can be done during new construction, during maintenance operations, or via retrofitting. It is presumed that when a random train passes, readings acquired by the subterranean cluster are interlaced with transition-zone condition information. Therefore, the objective of the work is to develop an analysis method for accessing this information.

Main activities: In this project, as a first evaluation step, a computational investigation is sought. Focus is placed on generation and interpretation of synthetic acceleration data in a virtual transition-zone. Synthetic measurements should be produced based on mechanical modelling of the problem, and include acceleration traces resulting from a train passage over a railway pavement containing an imperfection, e.g., localized surface unevenness, floating sleeper, etc. This data should then be utilized to develop an interpretation scheme for identifying the imposed damage.

Other studies related to this project can be envisioned, e.g., optimization of the sensing topology (i.e., number of sensors, positions), monitoring structural integrity, and detecting wheel-flats. These options will serve as topics in separate investigations; they are mentioned here to demonstrate that embedded (underground) sensing opens a wide range of opportunities for infrastructure monitoring.

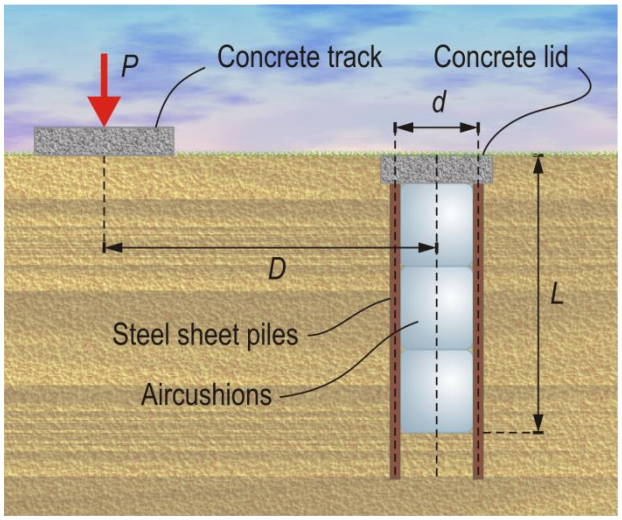
The project will be carried out in close collaboration with Prof. Eyal Levenberg, DTU. Eyal is an expert in pavement structures and sensing techniques.

Contact person: Lars V. Andersen

Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒

Vibration mitigation in civil engineering problems

Purpose: Sources to vibration cannot be avoided in the built environment. For example, traffic and heavy machinery may cause vibrations that can be transported over long distances through the soil. This is annoying for people in residential buildings as well as people working in offices or production facilities. A special problem concerns laboratory, hospitals and concert halls, where only a very small vibration level can be tolerated. To mitigate vibrations caused by external sources, a wave barrier may be introduced. A classical solution is to put an open trench between the source and receiver, but solutions that are more sophisticated have been proposed. As illustrated on the right, this includes aircushions that maintain the high efficiency of an open trench but keep the soil from collapsing and people, rain and objects from falling into the trench.



Several other possibilities exist, such as soil improvement by grouting or pile installation. Even "intelligent landscaping" has been suggested as a means of reducing vibration levels in the new MAX4 test centre near Lund in Sweden. The idea of the project is to investigate and optimize one or more methods of vibration mitigation and suggest materials, techniques or structures that can be used for dynamic isolation of buildings.

Main activities: Focus of the project may be development of a particular kind of wave barrier, or the problems related to vibration mitigation can be approached in a more general way. The activities of the project may include:

- Literature study of soil dynamics and wave propagation theory
- Numerical analysis of wave propagation in soil
- Optimal design of a wave barrier or wave impeding material
- Mitigation of wave propagation by intelligent landscaping or soil improvement
- Experimental analysis of a wave barrier.

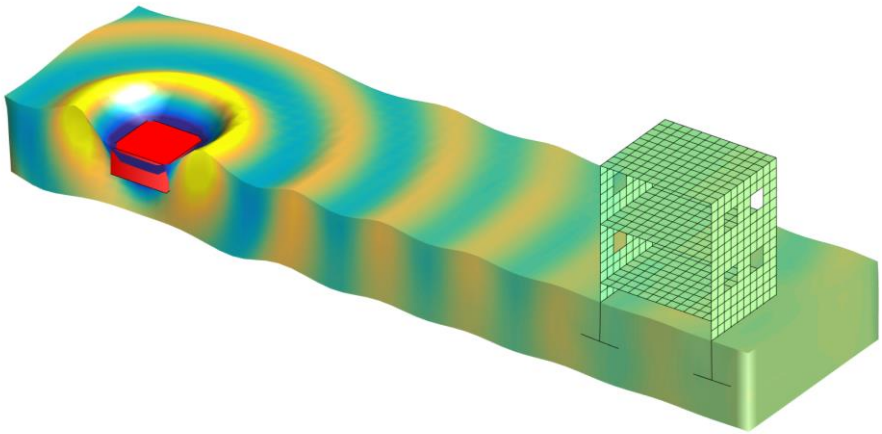
The workload related to theoretical investigations, experimental work and computer modelling may vary depending on the weight put on each item.

Contact person: Lars V. Andersen **Fit for 3rd semester project:** ☒

Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐

Numerical modelling of dynamic soil behaviour and soil–structure interaction

Purpose: Vibrations inside a building is a serious concern, especially in an urban environment or for structures near railway tracks. These vibrations can lead to structural damage to the building itself and reduce the quality of life of the inhabitants. Therefore, when building near a potential sources of vibrations, these effects need to be evaluated. However, numerical prediction of these effects is a complicated task, while on-site investigations are costly, time consuming and not always possible. The most commonly used numerical vibration prediction approach is the finite-element method. However, it has serious drawbacks for this kind of problem, which leads to extremely long computation times. Therefore, a number of semi-analytical approaches have been developed over the years to model the dynamic soil behaviour. These soil models can be coupled to finite-element structures to create a fully coupled soil–structure systems. Thus, greatly reducing the computational times. One of these models is currently being developed at Aalborg University. However, a number of concerns need to be addressed, and this would be the focus of this project.



Main activities: A number of cases would be modelled: These cases would include the soil and one or more structures interacting with it. They would be modelled using commercial software as well as the in-house model. Further, there is a possibility to further develop the in-house model with your own code. The main activities are:

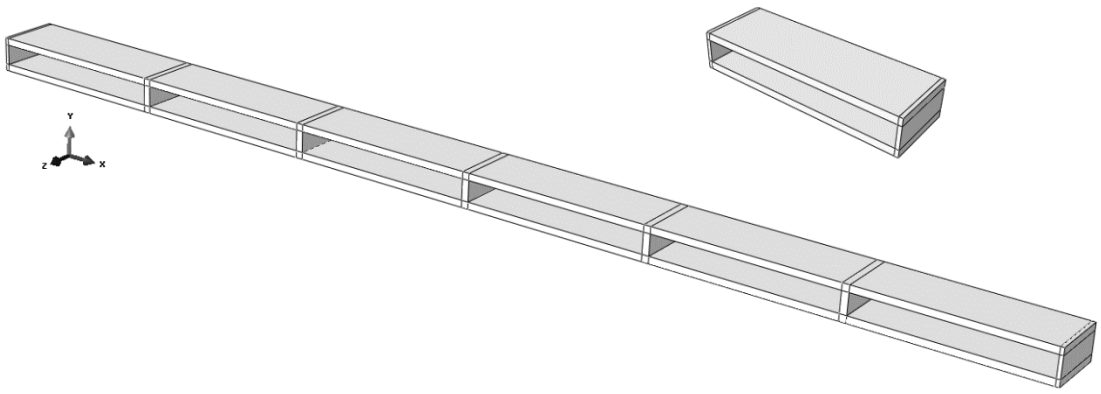
- Literature study of dynamic soil behaviour including different computational modelling approaches and soil–structure interaction
- Dynamic modelling of coupled soil–structure system using commercial (e.g. Abaqus) and in-house software
- Investigation of convergence together with various parameter studies of the models.

Contact person: Lars V. Andersen **Fit for 3rd semester project:** ☒

Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☒

Modelling and dynamic analysis of periodic structures

Purpose: In a periodic structure, the same geometry is repeated a number of times as illustrated below, where six identical cells are connected to form a beam. Such structures occur in many civil and structural engineering problems. For example, joists and studs are usually placed in a periodic manner in a wooden floor or wall panels, and tunnels may consist of a number of identical segments connected by gaskets at the joints. However, periodicity may also be introduced into structures that are usually not periodic, e.g., by placing additional masses or springs in a periodic manner. This may be beneficial, since periodicity within a structure has a documented effect on vibration transmission. Thus, so-called stop bands will form, in which wave propagation is attenuated dramatically. In a building structure, this can be utilized to avoid transmission of vibrations in frequency ranges where, for example, washing machines or elevator motors are known to induce vibrations. Theoretically, the reference cell may be repeated infinitely many times. Analysis of such structures can be carried out by means of Floquet theory which is a generalisation of Fourier theory. This can be combined with the finite-element method to establish models of railway tunnels, long wall panels, pipelined, etc.



Main activities: The following items may be part of the project work:

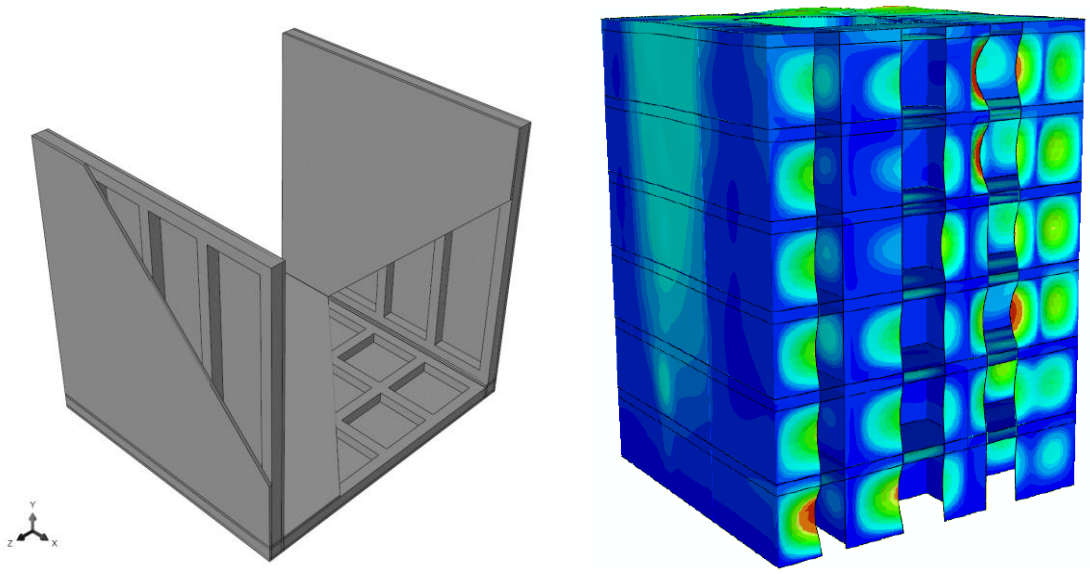
- Literature study of wave propagation in periodic structures
- Numerical modelling of a periodic structure (e.g., a tunnel, panel, or pipeline)
- Analysis of a periodic structure by means of Floquet theory
- Combination of finite-element analysis with Floquet theory
- Experimental analysis of wave propagation in a periodic structure
- Optimization of a periodic structure to minimize vibration transmission in a predefined range of frequencies.

Contact person: Lars V. Andersen **Fit for 3rd semester project:** ☒

Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☒

Noise and vibration in (lightweight) building structures

Purpose: Walls and floors in lightweight timber structures are usually constructed as wooden panels. Depending on the geometry, material properties and boundary conditions, such panels may resonate at different frequencies within the audible range, leading to emission of noise. Furthermore, the panels may serve as waveguides, transmitting noise from one room to another or between floors. The project may concentrate on a global model for a building—or transmission paths may be studied at a local level, e.g. at a junction between a wall and a floor. Alternatively, the project may focus on an optimized design of wall or floor panels where the studs or joists are placed periodically to minimize noise transmission in the audible range. Finally, a large or small-scale test may be carried out in the laboratory, or full scale testing can be performed to validate the computational model.



Main activities: The project is relatively open with concern to the problem to be analysed. The activities may include:

- Literature study of building acoustics
- Formulation of models for dynamic analysis of periodic structures
- Design of joints in building structures for mitigation of noise
- Parameter studies to identify the influence of geometry and material properties on sound transmission in lightweight building structures
- Finite-element modelling of coupled acoustics and structural vibration
- Experimental testing of structural dynamics and acoustics.

Contact person: Lars V. Andersen **Fit for 3rd semester project:** ☒

Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐

Propagation of sound in chimney made of pumice stone

Purpose:.The company Schiedel Isokern produces chimneys made of the natural material pumice stone that comes from the Icelandic volcano Hekla. An idea is that the material may not only be useful in terms of thermal insulation, but it might also have good properties regarding mitigation of sound propagation. This is important in countries like Norway, where central chimneys pass through several floors in multi-story dwellings. The floors may have a good sound insulation, but an ordinary chimney may serve as waveguide, transmitting sound from one flat to another.

The first idea of the project is to study sound and vibration transmission in chimneys made of pumice-stone-base concrete. Next, the possibilities of increased mitigation by combination with other materials or changing the properties of the chimney in other ways may be examined. The project will take place in close collaboration with Schiedel Isokern.

Main activities: The activities may include:

- Literature study of vibration and acoustics related to porous materials
- Analysis of pumice stone regarding its vibroacoustic properties
- Formulation of a numerical model for coupled vibration and acoustics
- Analysis of sound propagation in air subject to heat convection
- Analysis of vibroacoustic sound transmission through a chimney
- Design of new combined materials and new shapes for optimal design
- Analysis of a chimney interacting with two rooms in a building
- Experimental testing of structural dynamics and acoustics for a chimney.

Contact person: Lars V. Andersen

Theory: ☒☒☐ **Experimental work:** ☒☐☐ **Computer modelling:** ☒☒☒

Project Proposals in Wind Turbine Mechanics and Optimal Vibration Control

A number of project proposals are available in this area:

1. Dynamic Reliability Analysis and Determination of Design Criteria of Wind Turbines based on the Probability Density Evolution Method
2. Three Dimensional Turbulence Modeling for Wind Turbines based on Rapid Distortion Theory and the Evolutionary Phase Model
3. Semi-active Pitch Control of Wind Turbines against Dynamic Stall based on Partial State Observation
4. Semi-active and Active Vibration Control of Edge-wise Vibrations of Wind Turbine Blades
5. Optimal Non-linear Stochastic Control of a Cluster of Wave Energy Point Absorbers in Irregular Sea-states

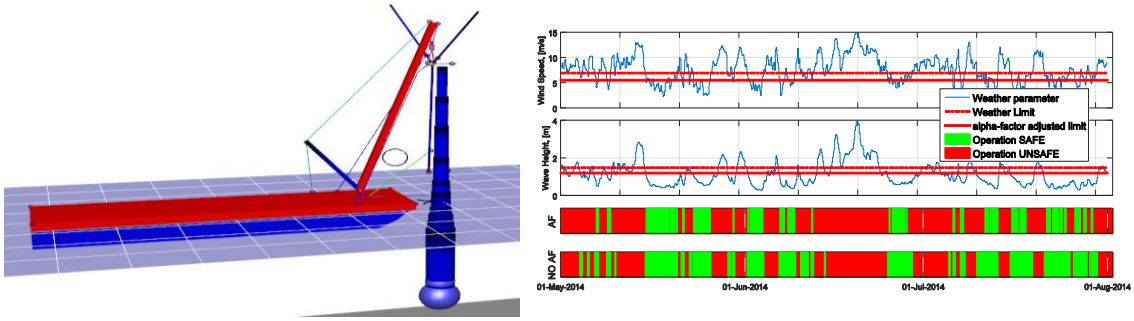
The proposals are in general not suitable for short 3rd semester projects.

A part of the projects may be carried out abroad as secondment to universities in China (Tongji University, Shanghai), Norway (NTNU) or Ireland (Trinity College Dublin).

Contact person: Søren R.K. Nielsen

Risk and Reliability-based weather window prediction for offshore operations

Purpose: Majority of installation and O&M operations off-shore are typically carried out by specialized ships and equipment that must be hired for the duration of the operation. Ship lease costs are directly connected to the operation duration, which in turn is comprised of the time it takes to perform the required activities offshore and waiting time for suit-able weather conditions (weather windows). Usually, the duration of offshore activities is clearly defined but changing met-ocean conditions limit the possibility to predict weather windows and waiting times. Predicting weather windows with higher accuracy would improve the estimates of transportation, installation, and O&M costs of a wind farm and in turn could possibly reduce the LCOE of offshore wind energy.



Typically, standard methods are limited to use of simple met-ocean parameters such as wind speed and wave height, as indicators of whether the operation is safe to attempt. However, the operational limiting factors are inherently physical – linked to physical properties and responses of the installation equipment and vessels, such as strength of lifting cables, maximum allowable motions, and velocities of vessels and lifted components, etc. The project aims to explore the feasibility of using such physical equipment limits within a Risk and Reliability – based framework.

Main activities:

- Literature study of current methods used to predict offshore location accessibility for installation/maintenance operations.
- Development of risk and reliability-based techniques for weather window prediction, based on statistical analysis of equipment response.
- Application of the aforementioned techniques to an example case study and comparison of the results against state-of-the art methods.

The project is connected to ongoing research, thus more specific activities could be defined.

Contact persons: John Dalsgaard Sørensen, Tomas Gintautas <tg@civil.aau.dk>
Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Reliability and Risk analysis of Wind Turbines – Planning of Operation & Maintenance

Costs to operation and maintenance (O&M) of offshore wind turbines are large, typically more than 25% of the cost of energy. Recent experiences from offshore wind farms indicate even larger costs. The costs consist of planned maintenance and corrective maintenance due to failure of components such as gearboxes, electrical components, blades, corrosion and fatigue. One main contributor to the high offshore O&M uncertainty and costs is the dependence on weather windows. In other engineering areas such as the offshore oil & gas industry and civil engineering bridges, rational approaches to planning of O&M have been developed. These approaches are based on risk and reliability-based techniques where it is possible to plan rationally future actions based on available information at the time of decision and models for costs and uncertainties.

The purpose of this project is to apply risk based techniques and Bayesian statistical methods for planning of O&M activities in practical applications (in cooperation with a wind farm operator, see below) incl. modelling of costs and risks in connection with O&M for offshore wind turbines. Further, the aim is to compare different O&M strategies considering a typical wind farm for a limited, but representative application area for O&M.

Main activities:

- Literature survey to give an overview of different methods for O&M planning
- Based on examples from other industrial areas (oil&gas) develop / describe how a Bayesian, risk-based approach can be used for O&M planning
- Illustrative example studies considering O&M for a limited number of components for a typical wind farm

The project will be connected to ongoing research projects.

Contact person: John Dalsgaard Sørensen
Theory: ☒☒☐ **Experimental Work:** ☐☐☐ **Computer Modelling:** ☒☒☐



Reliability assessment of existing and temporary structures

Generally reliability requirements and partial safety factors are related to permanent structures, e.g. with a design lifetime equal to 50 years. This is for example the case in the Eurocodes. For existing structures and for temporary structures, e.g. structures during execution and structures only used for a short time interval, no design requirements can generally be found in the codes, but are highly demanded by industry.

Both for existing and temporary structures it is sometimes argued, that the reliability level could be chosen lower than for permanent structures. But is that reasonable - e.g. for structures where people can be in danger in case of failure? And if the reliability level in some cases can de lowered, how much can the partial safety factors be decreased?

For existing structures, e.g. concrete bridges, information will often be available, e.g. in the form of measured concrete compression strengths of test samples, measured traffic loads, ... How can such information be used to assess the reliability of the structure, and eventually decrease the partial safety factors?

Main activities:

- Collect information from literature on assessment of reliability of temporary and existing structures
- Assess and describe methods to obtain the minimum reliability level using risk and reliability-based principles:
    - cost-benefit analyses: minimize lifecycle total expected costs
    - life safety principles: requirements by society
- Transformation of reliability level to 'reduced' partial safety factors and/or reduced characteristic loads.
- Select one or more illustrative structures (an existing structure and/or a temporary structure), and for the selected structure(s):
    - Stochastic modelling of loads and strengths
    - Assessment of minimum reliability level to be required
    - Estimation of evt. reduced partial safety factors

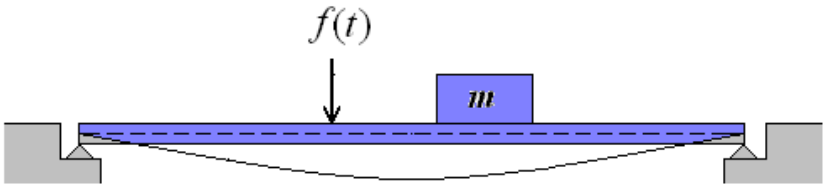
Contact persons: John Dalsgaard Sørensen

Theory: ☒☒☐ **Experimental Work:** ☐☐☐ **Computer Modelling:** ☒☒☐

Dynamic human-structure interaction

Background: In static calculus, passive (sitting/standing) humans are modelled as a rigid mass attached to the structure. In dynamics, humans in motion (people walking or jumping) are modelled as a dynamic load bringing the supporting structure into vibration.

Human in motion Passive person



In assessments of vibration levels of slender structures carrying humans (such as footbridges, stadia-structures, or office floors) these models are conventionally employed. But are they reasonable?

Purpose: The aim of the project is to study mechanisms of human-structure interaction focusing on areas where the models mentioned above are inadequate. Prior to codifying new models describing the phenomena, they need to be properly researched.

In the project you will plan and conduct experiments striving to highlight the true mechanisms of human-structure interaction on slender structures. Measured vibration data will allow you to calibrate alternative models of the interaction accounting for the flaws in existing models.

Implications of findings (new models of the interaction) you may illustrate through computer simulations of structural response to the dynamic loads generated by humans.

Contact person: Lars Pedersen

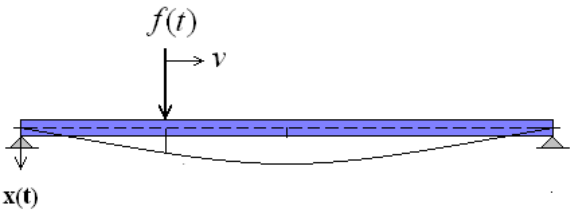
Theory: ☒☐☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☐

Dynamic human loading and stochastic models for estimating structural responses

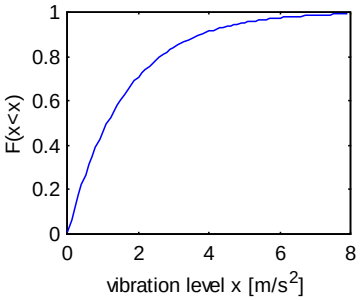
Background: Some civil structures are so slender that their modes of vibration may be excited by the basic frequency of human motion resulting in resonant structural action. The undesired resonant action may for instance occur in footbridges, stadia structures or in open-space office floors as a result of walking or jumping.

Codes and standards handle the phenomenon semi-empirically or even fully deterministic although fundamentally the loading generated by humans in motion is stochastic.

Purpose: The aim of the project is to develop and test stochastic models describing the loading and the structural response. An essential contribution would be to derive statistical distributions of structural responses to human-induced loading, as this would provide valuable information for assessing structural safety or serviceability. Specifically, the risk of exceeding various vibration levels is of interest although it is actually a parameter not given much/any focus in existing design codes.



Walking load when v > 0 m/s, "Jumping load " when v = 0 m/s



Statistical distribution of response

Through the project you will learn how to model the dynamic excitation of humans in motion, deterministically as well as stochastically. You will conduct parametric studies and numerical simulations to highlight essential implications of stochastic modelling of the phenomenon. Experimental verification of models is a possibility if so desired.

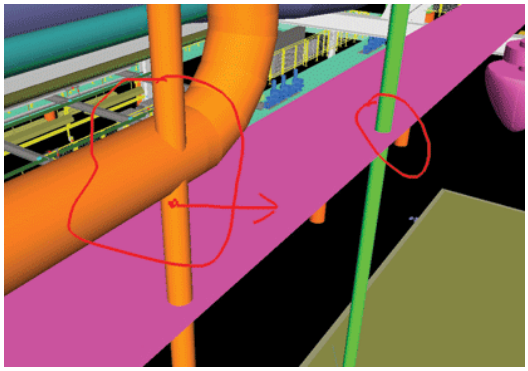
Contact persons: Lars Pedersen, Christian Frier

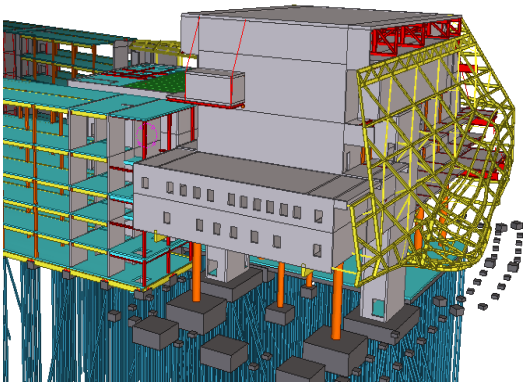
Theory: ☒☐☐ **Experimental works:** ☐☐☐ **Computer modelling:** ☒☒☒
(The amount of experimental work can be decided during the project)
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☐

Structural modelling and design coordination

Purpose: The construction industry is changing from traditional CAD drawings to more intelligent 3D object based models of the entire building. There are many attempts to improve the structural design process by making a better connection between object based CAD systems and structural simulation tools. The simulation tools can be more or less integrated with specific CAD systems or they may exchange data through open international standards. An important issue for the structural engineer is also the often complicated coordination with requirements from other disciplines such as architecture, HVAC etc. New IT tools are introduced to assist this coordination.

The purpose of this project is to identify critical elements of the integrated design and coordination process and examine how new methods and information technology can assist us in the future construction industry.





Main activities:

- Identify strength and limitations in current practices and identify opportunities with upcoming technologies in the area
- Review of enabling Information and Communication technologies (ICT), including software, data models, international standards, and human computer interaction tools
- Examine today's possibilities with existing tools
- Identify needs for new ways of working and from that derive a list of requirements on technical solutions
- Demonstrate possible solutions for the near future and describe issues for future development

The work may be in collaboration with a consulting engineering company.

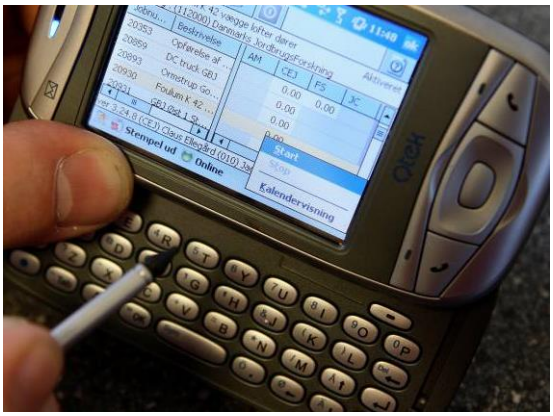
Contact persons: Kjeld Svidt

Theory: ☒☒☐ **Experimental Work:** ☒☒☐ **Computer Modelling:** ☒☒☐

Future information technology at the construction site

Purpose: In recent years, the construction industry has started changing from traditional 2D CAD drawings to more intelligent 3D object based models of the entire building. Such models give us a number of new possibilities for planning and controlling the activities at the construction site through advanced 4D models and possible links between the physical construction components and the virtual building model. New information and communication technology can improve the communication of correct instructions at the right time for the construction work as well as capturing information for quality assurance and as-built documentation.

The purpose of this project is to identify important problems within the area and propose solutions for future use of state-of-the-art information technology at the construction site.



Main activities:

- Identify current practices and problems in traditional construction projects
- Review of enabling technologies, software, hardware, international initiatives
- Test existing methods, software, hardware
- Identify needs and requirements for new solutions
- Build early prototypes with more or less functionality for initial tests

The work may be carried out in collaboration with a construction company.

Contact persons: Kjeld Svidt

Theory: ☒☒☐ **Experimental Work:** ☒☒☐ **Computer Modelling:** ☒☒☐

Finite-element modelling of reinforced concrete

Purpose: Reinforced concrete is widely applied as a construction material in civil engineering. Concrete is a complex material, both chemically and mechanically, and the formulation of material models demands a deep knowledge of the behaviour during casting, curing, utilization and, eventually, degradation. The introduction of reinforcement results in a composite material. In this case, the interaction between the concrete matrix and the steel reinforcement must be accounted for as well.



The idea in this project is to use advanced finite element calculations, e.g. via ABAQUS, to model reinforced concrete. Different methods should be compared, and a comparison with analytical methods should also be included. The project may focus on the analysis of a particular problem or structure.

Main activities:

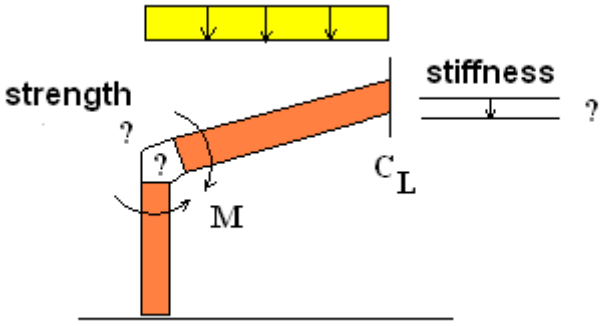
- Formulation of material models for concrete. This can be both built-in models in Abaqus and user supplied models, or any other software.
- Modelling of interfaces between concrete and reinforcement
- Finite-element analysis of reinforced concrete structures
- Comparison of FE models with standard design methods.

Contact person: Johan Clausen

Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☐

The corner of laminated timber frames

Purpose: Laminated timber frames are, for instance, desirable in structures where the aesthetics of the structure is in focus. A weak point in a timber frame is the frame corner and its strength and stiffness. But perhaps the corner does not need be made of wood?



Could a reinforced concrete structure or a steel structure be employed in the corner instead? At least the drawbacks of a corner made of wood might be removed and by employing wood in the remaining part of the frame, the frame would still visually appear much like a full wooden frame.

Main activities: The aim of the project is to explore the stiffness and strength of a timber frame employing different solutions in the corner of the frame (steel and/or reinforced concrete and using the full timber frame as reference).

In the project you will develop numerical and analytical models for the various solutions and full-scale tests will be conducted aiming at verifying the strength and stiffness predicted by your models.

Should your investigations reveal that solutions with steel or reinforced concrete in the corner of the frame are feasible (in terms of strength and stiffness) it might indicate a potential for a new type of frame structures.

The project might involve co-operation with external parties having an interest in mapping the potential of alternative solutions for timber frames.

Contact persons: Lars Pedersen, Christian Frier

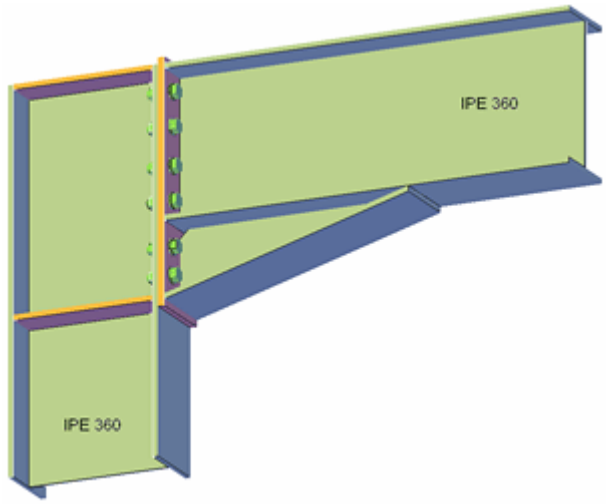
Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☐

Analysis of Joints in Steel Structures

Purpose: Joints in steel structures are frequently made using fasteners. These are not fully rigid which may play a role in terms of behaviour of the steel frame.

The purpose of the project is to investigate how flexibility in joints influences various global characteristics of the steel frame, and to study how Eurocode models these influences.

Another item of interest is to explore the load bearing capacity of joints made using fasteners (analytically, numerically, and experimentally) and to compare results with Eurocode models.



Main activities: The project is relatively open with concern to the problem to be analysed. However, in any case the activities will include:

- A mixture of analytical, numerical and experimental investigations
- Comparison of results with Eurocode models.

Contact persons: Lars Pedersen

Theory: ☒☒☐ **Experimental work:** ☒☐☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☐

Advanced Analysis of Steel Frames

Purpose: In ultimate limit state analyses of steel frames compression forces and bending moments are of concern, as they may lead to global instability manifested in either buckling or lateral torsion failure.

The design guide Eurocode sets up procedures for evaluating the ultimate limit state and actually, Eurocode (EC) suggests a number of different design approaches to choose from. Some EC-approaches are more simplifying than others, and this means that the final evaluation of the ultimate limit state depends on the method chosen for the evaluation. Or does it?

The purpose of the study is to highlight and quantify load carrying capacity of steel frames employing different methods, ranging from basic methods to more advanced methods (in all methods FE-analyses are required but to various degree of complexity).

In the initial part of the study, focus will be on analysing a reference steel frame, but in order to highlight the degree of differences in calculated load carrying capacities it is useful to extend the study. This, for instance, by studying a range of steel frame configurations or to conduct some other type of parameter study focusing on sensitivity of outcome of your calculations to input assumptions related to structural modelling.

Main activities: Besides, from a literature review focusing on the background for EC-guidance focus will be on

- Implementing and describing procedures
- Finite element modelling and analyses
- Parameter and sensitivity studies

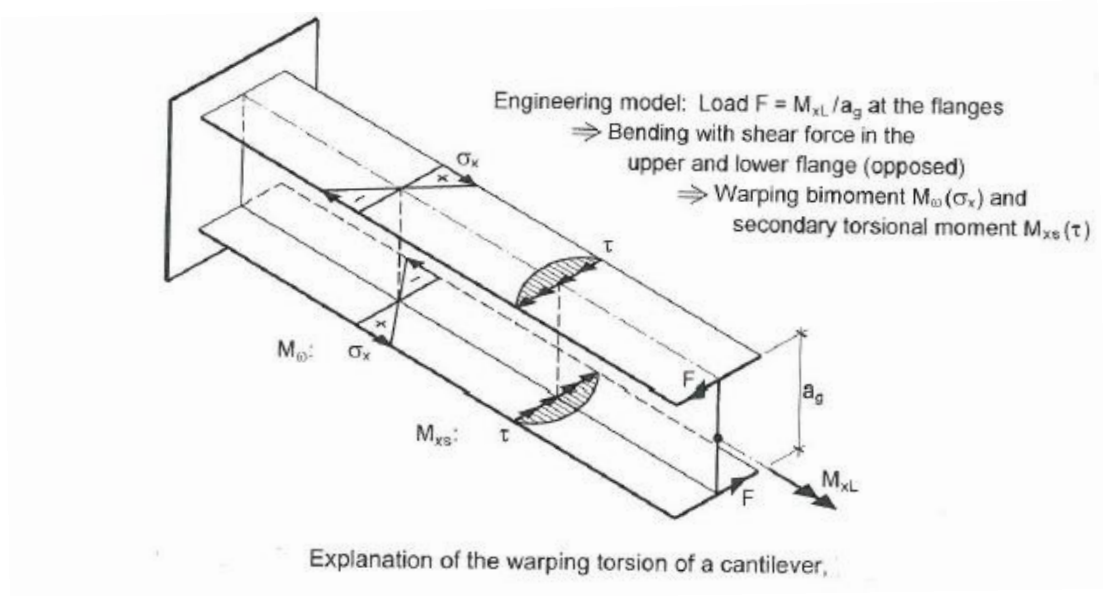
so as to provide an overview of load carrying capacities of steel frames as computed using different methods.

As part of the study it might be useful also to analyse one of the steel frames which recently collapsed due to heavy snow loads.

Contact persons: Lars Pedersen, Johan Clausen
Theory: ☒☐☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☐

Implementation of advanced beam finite elements

Purpose: The Eurocode for steel now makes is possible to use advanced finite element modelling to document the safety of steel structures. In the classical method interaction formulae for each steel member is used based on the linearly elastic section forces. The new method, however, allows for non-linear modelling and the documentation for larger portions of the structure at a time, i.e. not for every member. To be able to use this new method, non-linear models must be applied together with 3D elements. If possible, beam elements are preferred over shell and solid elements as the latter two result in soaring numbers of degrees of freedom. Many standard beam elements, however, do not account for the needed non-linear phenomena, or even the proper formulation for torsion.



Explanation of the warping torsion of a cantilever,

Main activities: Study, development and implementation of beam finite elements that incorporates one or more of the aspects of the advanced phenomena needed to use the new method in the steel Eurocode. These phenomena are large displacements, buckling (Euler and lateral torsional), torsional behaviour and material nonlinearities (plasticity). An interest in the finite element method and programming, for example using MatLab, is essential.

Contact person: Johan Clausen
Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

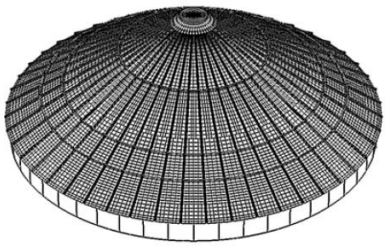
Example of company stay project

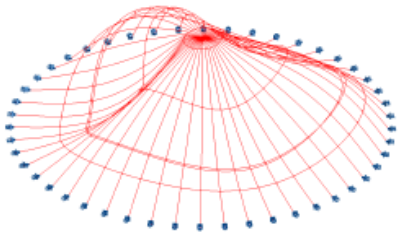
Analysis of snow-load induced damage on conical silo roof

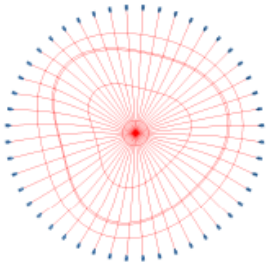
Company: Cowi, Aalborg Office
Company type: Consulting engineering company
Webpage: www.cowi.dk, www.cowi.com
Location: Aalborg

In the winter of 2009/2010 heavy snowfalls occured in Northern Jutland in Denmark. The ensuing large snowloads caused several roof collapses throughout the region. Among these were the several roofs of silos for crop storage. Crop silo structures are typically composed of corrugated steel sheets stiffened by steel profiles.

The company wanted to perform a detailed analysis of these collapses to assess the cause(s), and this was chosen as a project for the student doing the company stay.







The structure was studied by means of finite element analysis, including non-linear effects such as bifurcation buckling, large displacements and plasticity. Also, different detail levels in the modelling were compared, as was beam and shell models.

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